An investigation into university teachers’ and students' perceptions of problem solving in physics in higher education in Saudi Arabia.

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I certify that all material in this thesis which is not my own work has been identified and that no material has previously been submitted and approved for the award of a degree by this or any other University.

Signature: …………………………………………………………...

Abstract

This study was conducted to investigate university teachers' and students' perceptions of problem solving in physics in higher education in Saudi Arabia. The current study took into consideration the sociocultural notion that context is an important contributor to the learning process and impacts on the interaction between people. This study focused on aspects of the context, such as community, school, university, language, syllabus and classroom practices, that influence students' learning of problem-solving in physics.

An explanatory sequential mixed methods approach was used to collect data using two questionnaires (the Force Concept Inventory test and the Mechanics Base Line Test), semi-structured interviews, classroom observations and think aloud protocols. The study sample consisted of 31 participants in total, including ten preparatory-year students, eleven first-year students, five preparatory-year teachers and five first-year teachers.

The findings revealed that students found difficulty in understanding problems; they did not seem to know how to implement the steps of problem-solving (understanding the problem, devising the plan, carrying out the plan and looking back). Moreover, this study revealed that a number of social and cultural aspects played an essential role in influencing these students' learning of problem-solving in physics.

The study also revealed that students were fearful of asking their teachers questions when they did not understand. Likewise, this study emphasised the important role of providing a safe classroom environment to create social interaction between students and their teachers, and between students themselves, in order to enable students to think and access assistance to their performance, whether from their teacher or peers. Subsequently, this assistance improved students' understanding in physics lectures and their understanding of physics problems. Also, the study highlighted that a number of linguistic issues, such as the teacher's dialect or the use of English as medium of instruction, were an obstacle to students' understanding of mechanics problems, thereby causing an additional cognitive burden. In addition, this study found that students seemed not to have the opportunity to get assistance, such as in the form of feedback or questioning from their teachers, due to the huge

number of students in the class, which prevented teachers from guiding students' thinking while solving physics problems. It was also found that students' comprehension of Newtonian concepts was inadequate for successful problem-solving due to a lack of basic physics knowledge.

Dedication

To my mother, Hamdah, my father, Ateeq, and my wife, Hanna, for their unlimited support and encouragement, and to my beloved children, Albatool and Alwaleed.

May Allah's mercy surround them all throughout their lives.

To my sister, Noha, may Allah rest her soul.

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Chapter One: Introduction to the Study

1.1 Introduction

This chapter presents the rationale for this study and the research questions. In addition, it presents the significance of the study and an overview of the research design. Also, my personal interest is presented in order to show why I carried out this study. Finally, this chapter presents the terminology used in the thesis and highlights its structure by providing a brief description of each chapter.

1.2 Rationale of the study and research questions

Physics education generally aims to train students in the scientific method of thinking and to enable them to solve physics problems. Forawi (2016, p.54) pointed out that “the science curriculum plays a major role in providing opportunities for students to use and acquire higher-order thinking skills”. In this respect, research points to the numerous advantages that can be gained when teachers and students use thinking skills in general and more specifically solving physics problems in education. Algabory (2010), Mason and Singh (2016), Gok (2010) and Tao (2001) note that problem-solving skills enhance students’ level of eagerness for learning, increase their subject knowledge and improve their overall thinking skills, suggesting that academic achievements and thinking skills can be improved through enhancing problem-solving skills in physics.

Furthermore, with regard to thinking skills, the Ministry of Education (MOE) in the Kingdom of Saudi Arabia (KSA) attempted to raise and improve the quality of science education through, for example, the Developing Science and Mathematics Curriculum Project, for all stages of general education (primary, intermediate, secondary). As further detailed in Chapter Two, one of its principles is improving thinking skills and one of the goals of the university preparatory-year (a transition year from secondary school to the first-year of university) is to develop problem-solving skills and critical thinking. More specifically, it could be argued that students need to have these problem-solving and thinking skills “because a major goal of physics teaching and learning is problem-solving, the solution of exercises and problems is a major component of most physics classes” (Kim & Pak, 2002, p.759).

Moreover, the Saudi government has paid great attention to education in terms of budget spending to improve and develop the level of thinking and the quality of education among learners and provide them with the necessary skills to develop their thinking. For example, in 2017, the expenditure allocation in the budget of the education sector was estimated at 41 billion pounds compared with the 2010 budget which was 28 billion pounds (Ministry of Finance, 2017). In this context, “Science education in Saudi Arabia is receiving more attention than it has ever received before” (Almazroa & Al-Shamrani, 2015, p.3).

In light of the above, preparatory-year students are supposed to possess a solid background from their secondary school (where the Developing Science and Mathematics Curriculum Project has been applied) in terms of thinking skills, particularly problem-solving skills. Likewise, first-year students are supposed to possess a good background from secondary school and from the preparatory-year since they are taught a course called “Thinking and Learning Skills”.

However, in addition to my professional experience as a physics teacher in Saudi Arabia, a short pilot study was conducted (at the beginning of this study in 2015) among three university physics lecturers from the preparatory-year and the first-year at the University of Taif who were involved in teaching several physics modules. For this pilot study, the faculty members were asked several questions by means of email and telephone regarding the nature of the problems facing first-year and preparatory-year physics university students at the University of Taif. It was found that these teachers felt that students were not able to deal with different physics problems and that they had become accustomed to applying their knowledge in a habitual way; this means that students seemed to rely on memorisation and used ‘*plug and chug’* ways to solve physics problems. ‘Plug and chug’ can be defined as “procedural ways of solving problems and completing assignments that (1) allow you to get by without wasting time thinking, (2) do not require you to really understand what you are doing, and (3) protect your own limited understanding from being exposed” (Bella, 2003. p. 33). Teachers explained that, for example, if a teacher gave students different physics problems by simply changing some figures or by modifying the order of the problem components, students might not be able to address the problems in an appropriate way.

Likewise, despite the efforts by the MOE to raise the quality and the level of education, there has been a notable decrease in marks in the general physics course in the preparatory-year and in the first-year mechanics course at Taif University over the ten academic years from 2006 to 2015 (Admission and registration of Taif University, 2016), as explained in Chapter Two (see Table 2.1 and Table 2.2). Therefore, this leads to raising the question of what might prevent university students from using problem-solving skills effectively in their learning. This is because students are supposed to have acquired these skills during their studies at school and university.

Consequently, the current study sought to investigate this phenomenon from different angles. Firstly, students' basic physics concepts and their problem-solving skills were measured, using the Force Concept Inventory (FCI) and the Mechanics Baseline Test (MBT), in order to understand their readiness to do problem-solving in physics. It was thought essential to measure students' basic concepts in mechanics and problem-solving skills because a solid understanding of Newtonian concepts is essential for successful problem-solving (Hestenes, Wells & Swackhamer, 1992). Also, physics concepts need to be considered in order to enhance students' understanding of physics problems (Eshetu & Assefa 2019).

Secondly, this research considered fundamental socio-cultural issues, such as context and social interaction, as determining factors in the learning process (John-Steiner & Mahn, 1996; Rogoff, 2003) thereby affecting students' problem-solving skills. Therefore, it was essential to gain an understanding of students' and teachers' perceptions of students' problem-solving in physics. Hence, the socio-cultural theory was relevant in its focus on contextual aspects, such as the social environment, the learning environment or the language, that may impact on students' problem-solving skills in physics. Indeed, "there is a strong link between culture and learning that is reflected in how people prefer to learn and how they tend to process information" (Samovar, Porter & McDaniel, 2009, cited in Alebaikan, 2010). In addition, as explained by Scott and Palinscar (2013), the aim of sociocultural theory is "to explain how individual mental functioning is related to the cultural, institutional and historical context; hence, the focus of the sociocultural perspective is on the roles that participation in social interactions and culturally organised activities play in influencing psychological development” (p. 1).

Based on this, it seemed important to gain a deeper understanding of how students’ practices and perceptions are shaped within the wider context. Hence, this study adopted sociocultural theory ‘‘to explicate the relationships between human action, on the one hand, and the cultural, institutional, and historical situations in which this action occurs, on the other’’ (Wertsch, Del Rio & Alvarez, 1995, p. 11).

Thirdly, this study was conducted in the preparatory-year and first-year at university because preparatory-year students should have gained a solid background from secondary school in thinking skills and problem-solving skills. Likewise, first-year students should have acquired adequate knowledge and skills from secondary school and from the preparatory-year because they are taught a course called “Thinking and learning skills”. Therefore, investigating university teachers’ and students’ perceptions of students’ problem-solving in physics in these two years might help both teachers and students to reach the goals of physics education in terms of students’ thinking skills in general and problem-solving skills in particular.

Fourthly, the voices of university students and teachers could give an insight into how the Saudi context and various social and cultural elements impact and affect students learning problem-solving in physics. However, through searching the database in the Saudi Digital Library and King Abdullah Library, to my knowledge, students’ and teachers’ voices seem to be absent from previous studies conducted in the KSA. Thus, in the current study, the focus is on gaining a better understanding of university students’ problem-solving in physics through university teachers' and students' perspectives.

With respect to the literature on problem-solving, the research which has been conducted in universities and schools has focused on the positive impact of different approaches, such as peer instruction or structured problem-solving strategies, to promote students’ problem-solving ability and their performance in physics. For example, some research has focused on the development of conceptual understanding through structured problem-solving in physics, suggesting that learners familiar with structured problem-solving strategies have a better conceptual understanding of physics, thereby adopting a more conceptual approach to problem-solving (Gaigher, Rogan & Braun 2007).

Another study (Maries, 2013) looked at the role of multiple representations in physics problem-solving and found that productive diagrams could help students to solve problems, sometimes in conjunction with a mathematical approach. However, the findings of this study also suggested that students' poor performance, even with the use of diagrams, was due to a lack of conceptual planning, whereby they did not follow an adequate systematic procedure when attempting to solve problems.

Maries and Singh (2018) investigated the effectiveness of drawing productive diagrams in solving physics problems and found that this approach can enhance university students' problem-solving performance. For instance, they found that students who drew productive diagrams performed better than students who drew unproductive diagrams.

Moreover, Ornek (2009) investigated how modelling-based instruction, combined with an interactive-engagement teaching approach, promoted students' problem-solving abilities. It was found that such an approach impacted positively on students' physics problem-solving skills and helped them to think like experts. Hence, it was concluded that the modeling-based interactive teaching method could potentially help in enhancing students' problem-solving ability, especially in an introductory physics course.

In addition, Gok (2014) examined the effects of peer instruction on performance, gender gap, conceptual learning and problem-solving in physics, and found that peer instruction had the most significant impact on students' conceptual learning and problem-solving skills compared to traditional instruction. In another study examining the effects of strategic problem solving with peer instruction on college students' performance in physics, Gok (2015) found that students changed their perspective on physics problems and that their achievement test performances improved. Gok suggested that the method was beneficial to connect the quantitative solution with concepts. Furthermore, another study (Teodorescu, Bennhold, Feldman, & Medsker, 2014) found that curricular reforms could improve students' attitudes and problem-solving performance.

Despite the above studies, which were conducted in various contexts, there has been little research on students' problem-solving in physics in terms of the factors hindering students to solve physics problems. One of the few studies was by Byun, Ha and Lee (2010), who conducted quantitative research to understand university students' difficulty in upper-level mechanics problem-solving processes and found certain hindering factors. The three main factors were: (1) the inadequate level of mathematical skills, (2) an insufficient knowledge base in physics, and (3) the students' inability to fully comprehend the problem they were faced with. Likewise, Ogunleye (2009) studied quantitatively teachers' and students' perceptions of obstacles to students' problem-solving in physics and found two factors: lack of understanding of the physics problems and lack of mathematical skills. Also, Becerra-Labra, Gras-Martí and Torregrosa (2012) conducted a quantitative study of the effects of a problem-based structure of physics course contents on conceptual learning and on students' ability to solve problems. It was found that the most problematic issues university students had to deal with in problem-solving were related to an insufficient level of specific skills, such as linking prior knowledge to the new problem situation, performing a qualitative analysis, elaborating a strategy for solving the issue, and performing suitable calculations.

Another study was conducted by Zewdie (2014), who investigated problem-solving approaches of university students in physics courses and found various reasons why they were sometimes unable to solve physics-related problems, including the shortcomings of traditional teaching approaches, students' nervousness, lack of interest in the subject, or insufficient knowledge of mathematics.

However, the above studies did not take into account the perceptions of university students and teachers in the wider context, even though this is an important contributor to the learning process. Hence, there is a lack of clarity regarding how the wider context in which the students lived and interacted socially may have influenced their learning of problem-solving in physics. Consequently, the present study focuses on students' basic physics concepts, their problem-solving skills, university teachers' and students' perceptions of students' problem-solving in physics in two different years, together within the sociocultural context. As far as I am aware, no studies have investigated these aspects together within the sociocultural context, although this approach should lead to a greater understanding of students’ problem-solving in physics.

Furthermore, this issue needs to be further investigated, and more specifically in the Saudi context, as no studies conducted in the KSA have investigated the perceptions of university students and teachers about students' problem solving in physics in higher education and the reasons behind students’ difficulties in solving physics problems, within the sociocultural context.

A number of studies, however, have been conducted in the KSA in relation to problem-solving skills (e.g. Albaker, 2012; Alshaya, 2018; Sawafetah, 2008; Yaseen, 2013) but these have focused on the relationship between problem-solving and academic achievement, creative thinking or deductive thinking and on the verbal structure of the problem, physics laws, basic mathematical skills, and graphics or diagrams. Also, Aljebally (2013) conducted a study in the KSA which aimed to identify the level of problem-solving skills among university students and the differences between them based on gender, specialisation and academic level by measuring the participants’ level of problem-solving skills. The study showed no differences between male and female students in problem-solving skills but differences in terms of specialisation and academic levels. Another study in the KSA (Alshaya, 2014) addressed the difficulties facing preparatory-year students in physics courses through asking faculty members to assess these difficulties and through analysing students' answers in physics problems in their final examinations.

However, none of these studies have paid enough attention to the perceptions of university students and teachers about students' problem solving in physics and the factors influencing problem-solving success considering the wider context in which the students live. Investigating these perceptions and identifying these factors could, however, help both teachers and students to reach the goals of physics education and improve students’ thinking in solving physics problems at the university level. Thus, this study was conducted to investigate university teachers’ and students' perceptions of problem solving in physics in higher education in Saudi Arabia, and it sought to answer the following research questions:

1. To what extent does the level of Taif University preparatory-year and first-year students' understanding of the basic concepts in mechanics allow them to solve physics problems adequately?
2. What strategies are used by Taif University preparatory-year and first-year students when they deal with physics problems, and why do they use such strategies?
3. What are students' and teachers' perceptions about physics teaching methods?
4. What are students' and teachers' perceptions of the institutional factors impacting on students' learning of problem-solving in physics?
5. What are students' and teachers' perceptions of the socio-cultural factors impacting on students' learning of problem-solving in physics?

1.3 Significance of the study

The main aim of this study was to investigate university teachers' and students' perceptions of students' problem-solving in physics in higher education in Saudi Arabia. Sociocultural theory was adopted in this study as a theoretical framework to focus on aspects of the context that may influence physics problem-solving. By shedding light on several aspects of the Saudi societal context, this study also sought to understand the factors which influence students with respect to physics problem-solving, from the perspectives of students and university teachers within the Saudi sociocultural context. In this regard, Schoen (2011, p.18) claimed that "sociocultural research necessitates the added dimension of thinking about the phenomenon in a way that sees the big picture of the embedded context in which it occurs". Thus, I believed that adopting this framework should allow me to gain a deep understanding into why students find difficulties in solving physics problems at the university level.

Based on these premises, the current study took into consideration the socio-cultural perspective, as it was believed that context is an important contributor to the learning process and that it could help in understanding the nature of the interaction among students and with their teachers, and the institutional and cultural setting. Therefore, this study might play an important role in providing guidance and information to decision makers in the MOE to identify factors that may affect students' learning of problem-solving in physics in order to improve the educational process and the teaching and learning of physics, whether in schools or universities, in relation to thinking skills in general and problem-solving skills in particular. Also, the results of this study could contribute to raising the awareness of officials about the importance of the development of university programmes in relation to the professional development of teachers with regards to the teaching and learning of problem-solving skills at the university level and other pedagogical aspects of the teaching and learning of physics.

1.4 Overview of the research design

As mentioned earlier in this chapter, this study focused on students' problem-solving in physics. It used multiple sources of evidence, including questionnaires, semi-structured interviews, classroom observations and think aloud protocols to investigate problem-solving in physics within a real-life context (Robson, 1993) by collecting data from the participants (see Chapter Four). Also, a variety of quantitative tools were used, such as the FCI and the MBT tests. Moreover, interviews, classroom observations and think aloud protocols were employed to collect qualitative data.

This study utilized a pilot study of quantitative as well as qualitative methods. The pilot was used to test and verify the research tools in order to identify potential problems which might arise during their implementation. Two quantitative questionnaires (FCI, MBT) were distributed to first-year and preparatory-year students at the University of Taif. The results of these quantitative methods informed the follow up qualitative data collection because the quantitative results alone did not provide enough evidence of the factors affecting students' learning of problem-solving in physics. In other words, because this study also sought to understand the factors which influence students with respect to physics problem-solving, from the perspectives of students and university teachers in higher education in Saudi Arabia. (see Section 6.6 and 6.7 in Chapter Six), it was important to engage with students of both years in in-depth discussions about the difficulties they faced when solving physics problems and about their understanding of physics concepts. Therefore, physics lectures were observed in both years, interviews were conducted with students and teachers of both years and think aloud protocols were carried out with students from both years. The following diagram explains the procedures and methods of data collection.

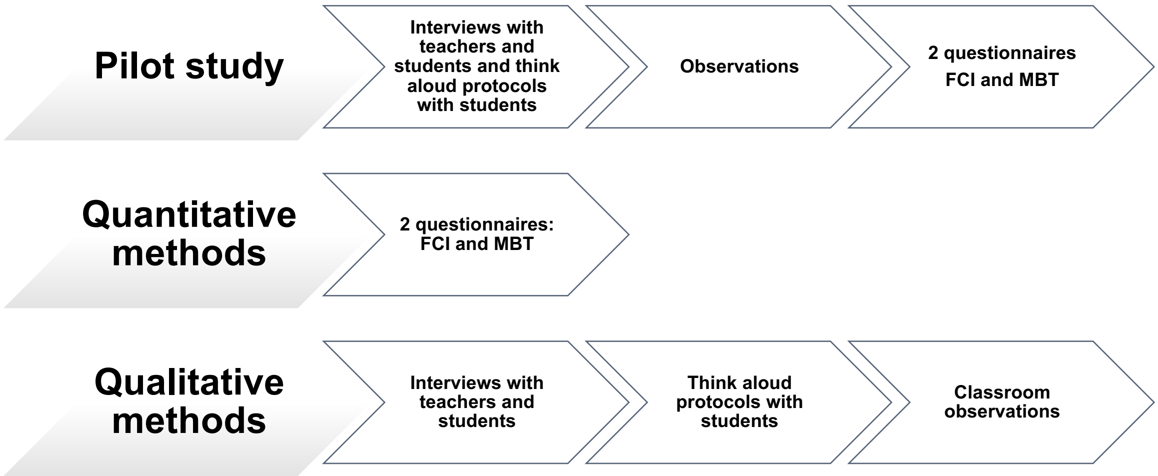

Figure 1.1: Procedures and methods of data collection

Thus, this study gathered important findings about the issue under investigation as will be presented in the Findings and Discussion Chapters (for more details, see Chapter Four).

1.5 Personal interest

Before obtaining a scholarship to complete doctoral studies abroad, I worked in the College of Education at Taif University as a lecturer in physics education. During that time, I witnessed the low achievement of students in physics and their difficulty dealing with physics problems. Based on these concerns, I attempted to understand the reasons for students' low ability and achievement in physics problem-solving. Preparatory-year students should have gained a solid background in school because of the Developing Science and Mathematics Curriculum Project which is founded on the improvement of thinking skills. Also, first-year students were supposed to possess a good background from their secondary education and from the preparatory-year since they were taught a course called "Thinking and Learning Skills"; and one of the goals of the preparatory-year is to develop students' problem-solving and critical thinking skills. Consequently, when I started this PhD journey, I decided to empirically investigate this issue through an exploration of students' problem-solving in physics in higher education in Saudi Arabia.

1.6 Terminology

This section highlights the key terms used in this thesis: thinking, thinking skills and problem solving:

Thinking is a developmental phenomenon that occurs through a series of stages in life, and that is influenced by several factors, such as how the thinker was raised, his or her motivation, abilities or education (Al-Atoom, Al-Jaragh, & Beshara, 2007). According to Beyer (1988), on the one hand, thinking is a comprehensive course of action, in which "we mentally manipulate sensory input and recalled data to formulate thoughts, reason about, or judge" (p. 72), that is done in order to provide significance to life events.

Thinking skills are tactics the mind purposefully employs to solve problems and accomplish goals.

Gagne (1977), defines *problem-solving* as a thinking process or mental representation whereby learners identify a range of rules they have previously acquired that can be implemented to solve a new problem. Zaitoon (2003) defined problem-solving as a mental representation that consists of a series of steps followed by an individual in order to reach a solution to a problem.

Polya (1957) pointed out that *the steps of problem-solving* are: understanding the problem, devising a plan, carrying out the plan and looking back.

1.7 Structure of the thesis

This thesis consists of eight chapters, as highlighted here. First, this chapter, the introduction, has presented the rationale for the current study and the research questions. Also, it has set out the significance of the study and provided an overview of the research design. This chapter has also highlighted the terminology used in the thesis is concluded with an overview of the structure of the thesis including a brief summary of each chapter.

In Chapter Two, the Saudi context is presented, and an overview of the study context is highlighted in order to give a general background about the Kingdom of Saudi Arabia and its educational system. Finally, the direct context where the study was conducted is also presented, that is, Taif University.

Next, Chapter Three is the Literature Review. This chapter explores and critically discusses the literature, focusing on the area of thinking skills and problem-solving. Moreover, it presents the theoretical framework of the study, which gives a wider picture of students' problem-solving in physics in higher education in Saudi Arabia.

Chapter Four presents the methodology of the study. This chapter discusses the study's philosophical assumptions, its research methodology and methods of data collection and analysis. In addition, this chapter addresses the ethical issues associated with the conduct of this research.

Chapter Five reports the quantitative findings in relation to preparatory-year and first-year students. This chapter highlights the results obtained from the analysis of the data gathered from the two questionnaires which are: the FCI and the MBT.

In Chapter Six, the qualitative findings are highlighted. The chapter reports on the qualitative data analysis from the interviews, classroom observations and think aloud protocols.

In Chapter Seven, the main findings of the study are discussed in light of the literature and through the lens of sociocultural theory.

Finally, Chapter Eight concludes the thesis by providing answers to the research questions and highlighting its contribution to theory and practice. Further, the conclusion addresses the limitations and implications of the study. Finally, the thesis ends with a number of recommendations for further research.

1.8 Summary of the chapter

This chapter has presented the rationale for this study and the research questions. It has also introduced the significance of the study and provided a brief overview of the research design. Finally, the chapter has presented the terminology used in the study and the overall organisation of the thesis. Following these introductory premises, the next chapter highlights the Saudi context and sheds light on a number of societal aspects of Saudi Arabia as this is believed to influence issues related to physics problem-solving.

Chapter Two: Context of the Study

2.1 Introduction

The present study aims to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. Also, because “there is a strong links between culture and learning that is reflected in how people prefer to learn and how they tend to process information” (Samovar, Porter & McDaniel, 2009, cited in Alebaikan, 2010), it is useful to provide basic information about the context in which this study was conducted in order to allow the reader to gain a better understanding of the Saudi context. Moreover, this study argues that the context makes an important contribution to the learning process and to the interaction between people within this context. Therefore, socio-cultural theory should be useful in focusing on aspects of the context that may influence the issue of physics problem-solving. Consequently, this chapter starts by giving an overview of the Kingdom of Saudi Arabia (KSA) and goes on to shed light on the educational system of the country. Then, the chapter moves on to examine certain attempts that have been made to develop science education in Saudi Arabia with particular respect to physics. Then, the chapter focuses on the specific context where this study was carried out, which is the preparatory-year and first-year at Taif University.

2.2 Overview of Saudi Arabia

Saudi Arabia is located in the far south-west of Asia. Saudi Arabia occupies four fifths of the Arabian Peninsula with an area of about two million square kilometres. The total population of Saudi Arabia is 31.7 million (General Authority for Statistics, 2017).

Saudi Arabia is considered the heart of the Islamic world because it hosts the two holy cities of Mecca and Medina. More than two million pilgrims from around the world come to perform the Hajj pilgrimage each year, which grants Saudi Arabia an important place in the region and in the world. Economically, Saudi Arabia has achieved strong growth rates in recent years, benefiting from high oil prices (Al Darwish et al., 2015). This has been reflected in all sectors, including the education sector, to which the state has paid close attention compared to other sectors. For example, in 2017, expenditure allocations for the budget of the education sector were estimated at more than 200 billion Saudi Riyals compared with the 2010 budget which was over 137 billion Riyals (Ministry of Finance, 2017). In this regard, Alshannag, Tairab, Dodeen and Abdel-Fattah (2013, p.653) mentioned that “Saudi Arabia is one of the countries that have invested heavily in education to maintain the country’s future development and prosperity”.

2.3 Educational system in Saudi Arabia

2.3.1 Ministry of Education

The establishment of the education system in Saudi Arabia coincided with the establishment of the Ministry of Education in 1954, which laid the foundation for male education. Later, in 1960, the General Presidency for Girls’ Education was established and, several years later, male and female education were merged under the Ministry of Education. It is also important to mention that the state provides free education at all levels for all citizens (Alblaihed, 2016, Ministry of Education, 2017).

General education consists of four stages: (1) the pre-school stage, (2) the primary stage, (3) the intermediate stage, and (4) the secondary stage. The pre-school stage caters to children between three and five years old and is not compulsory. The primary stage begins at the age of six and lasts six years. During this stage, the achievement of the students and their transition to the next stage depends on a continuous evaluation; at the end of this stage students obtain a primary stage certificate. Next, the intermediate stage starts from the age of twelve and lasts three years, whereby students are required to pass examinations in order to obtain a middle school certificate. Finally, the secondary stage starts from the age fifteen and is three years long. After the first secondary year, students have to choose a specialisation, either scientific or literary, and must pass yearly tests during this stage. At the end of the secondary stage, students take an examination, the general certificate of secondary education, which grants them access to university degree courses according to their specialisation (Alreshidi, 2016; Alsenaidi, 2012; Ministry of Education, 2017).

2.3.2 Ministry of Higher Education

The Ministry of Higher Education was established in 1975 to assume responsibility for supervising, planning and coordinating the Kingdom’s needs in the field of university education in order to provide national cadres specialised in administrative and scientific fields to serve the national development goals. The number of public universities has reached twenty-five, in addition to ten private universities, taken together these have a high capacity and are spread geographically across the regions of the Kingdom. These universities have a great deal of autonomy in the administrative and academic fields. The state provides free education in public universities, and graduates and postgraduate students who do not work in any governmental institution are given a stipend during their studies. The amount of the stipend for students studying scientific disciplines is SAR 1,000 whereas for students in the literary disciplines, this stipend is SAR 850. Postgraduate students also receive a grant of SAR 900 according to the scheduled duration of their programme of study.

All these universities were linked to the Ministry of Higher Education, but they have been under the supervision of the Ministry of Education since the Ministry of Education and the Ministry of Higher Education were merged into one in 2015, simply called the Ministry of Education (Ministry of Education, 2017). The objectives of the Ministry of Education are the following (Ministry of Education, 2017):

1. Building students' Islamic, national, and intellectual personality in terms of knowledge, skills, and values.
2. Providing admission opportunities to students so they can join education.
3. Developing the criteria needed for the selection and qualification of teachers, as well as developing teachers' competencies, and motivating them.
4. Promoting quality and upgrading the qualitative level of education.
5. Expanding the construction and maintenance of educational buildings and facilities.
6. Producing, disseminating and employing scientific research and knowledge, and expanding higher postgraduate programmes.

7. Expanding private education with a view to achieve the development objectives.
8. Upgrading the level of education outputs, in compliance with the requirements of development, as well as with the needs of the society.
9. Developing the regulatory environment and activating governance.
10. Granting overseas scholarships to talented students with a view to meet the needs of development, and to exchange knowledge.
11. Optimally employing information and telecommunication technology.
12. Diversifying the education funding resources and investing in education.
13. Enhancing local and international partnerships.

2.4 Development of science education in Saudi Arabia

In the Kingdom of Saudi Arabia, attention has been devoted to developing and improving science education in general and physics education in particular, in terms of objectives, content and teaching methods such as the Excellence Research Centre of Science and Mathematics Education (ECSME), the Developing Science and Mathematics Curriculum Project and a centre specializing in the development of Science, Technology, Engineering and Mathematics education (STEM).

2.4.1 The Excellence Research Centre of Science and Mathematics Education (ECSME)

The Excellence Research Centre is part of the developmental efforts made by the Ministry of Education, which launched a series of reforms aimed at improving the efficacy of education in the Kingdom. One key area of focus in education reform has been science and mathematics capability; hence, the Ministry of Education decided to fund The Excellence Research Centre of Science and Mathematics Education. The Centre was established in 2007 at King Saud University and its goals are as follows:

1. To establish research priorities for science and mathematics education in general and higher education in Saudi Arabia.

2. To conduct research studies and projects to diagnose the status and reality of science and mathematics education which lead to quality science education in both general and higher education in Saudi Arabia.
3. To encourage and guide researchers to become leaders of future advances in science and mathematics education through conducting cooperative programmes for the purpose of developing specialized research and authorship, graduate theses and dissertations, as well as student projects.
4. To create and disseminate knowledge and information for the purpose of advancing state-of-the-art science and mathematics education.
5. To contribute to the professional development of researchers in science and mathematics education in order to generate leaders for future advancements in science and mathematics education.
6. To conduct outreach research work and consultations in science and mathematics education for institutions and government entities.
7. To create partnerships with national, regional and international institutions in order to develop quality science and mathematics education and to build effective bridges and networks for the transfer of knowledge and research expertise.
8. To develop a joint intellectual and common scientific vocabulary in science and mathematics education, at the pre-university and university levels. (King Saud University, 2017)

2.4.2 Developing Science and Mathematics Curriculum Project

The Developing Science and Mathematics Curriculum Project is one of the leading educational projects in the region and aims at the comprehensive development of mathematics and science education through the development of curricula, teaching materials, assessment, e-learning and professional development. This project is based on the translation and harmonisation of educational materials that have proven to be effective in improving education. Moreover, the project is based on the alignment of distinct global chains of mathematics and science school book publishers, such as McGraw-Hill, for all stages of general education (primary, intermediate, secondary) in Saudi Arabia, and to benefit from international expertise in this field, in line with developed countries, to build a positive generation capable of solving its problems and the problems of its society. The vision of this project is to develop the abilities, creativity and skills of public education students in Saudi Arabia, so that they are able to gain a deep understanding of the scientific material, build new concepts, solve problems, innovate and develop products, communicate and use technology in accordance with the latest international scientific standards to meet the needs of the evolving labour market and the society's values. At the end of the project in 2016, it was expected that there would be curricula and accompanying educational materials and electronic teaching of science and mathematics materials for all stages of public education according to national expertise professionally developed to reach an advanced world level (Alshaya & Abdul Hamid, 2011). The project's philosophy is based on the following ten principles (Ministry of Education, 2006, p. 18):

1. learner-centred learning
2. increasing students' interest using multimedia tools
3. learning with multiple entries
4. knowledge exchange, communication and representation in multiple ways
5. learning through collaborative work
6. active learning based on exploration and inquiry
7. improving thinking skills
8. developing decision making skills
9. developing learner abilities to deliver planned initiatives
10. linking learning to real life contexts.

Considering the above-mentioned recent educational reforms to develop the science and mathematics curricula in the Kingdom, students are supposed to possess sound foundations from their secondary school education, in terms of thinking skills, in general, and problem-solving skills, in particular. In addition, the Saudi government has paid great attention to education in terms of budget spending to improve and develop the level of thinking among learners and provide them with the necessary skills to develop their thinking. In addition, throughout the university stage it is assumed that students can comprehend increasingly complex and intricate scientific knowledge. According to Piaget, it is assumed that students at this age have reached the formal operational stage in their cognitive development (Nutta, Bautista, & Butler, 2011).

In addition, preparatory-year students are supposed to possess a solid background from their secondary school (where the Science and Mathematics Curricula Development Project has been applied) in terms of thinking skills, particularly problem-solving skills. Likewise, first-year students are supposed to have acquired basic knowledge and skills from secondary school and the preparatory-year since they have been taught a course called "*thinking and learning skills*". Despite the efforts of the Ministry of Education to raise the quality and the level of education, there has been a notable decrease in marks in the general physics course in the preparatory-year and in the mechanics course in the first-year in Taif University over the ten academic years between 2006 to 2015, as shown in Table 2.1 and Table 2.2 below (Admission and Registration of Taif University, 2016).

Therefore, this raises the question of the thinking skills that students are supposed to acquire during their studies in school and university. This is why the current study seeks to investigate students' problem-solving in light of the sociocultural theory. Most studies (e.g. Albaker, 2012; Aljebally, 2013; Alshaya,2014; Sawafetah, 2008; Yaseen, 2013) conducted in Saudi schools or universities (only Aljebally and Alshaya conducted a study at university) have focused on the relationship between problem-solving and academic achievement, creative thinking and deductive thinking, or on identifying the level of problem-solving skills and the difficulties facing students in physics courses. Hence, there is a lack of research in the KSA on students' problem solving in physics in higher education based on university teachers' and students' perspectives about the factors which could help both teachers and students to reach the goals of physics education and improve students' problem-solving ability in physics.

Table 2.1: Academic achievement in the mechanics course in Taif University over ten academic years

Score	**Below 60**	**60-69**	**70-79**	**80-89**	**90-100**
Year			**Percentage**		
2006	19.61%	39.22%	25.49%	11.76%	3.92%
2007	8.53%	34.88%	31.78%	17.05%	7.75%
2008	13.75%	23.13%	20.00%	24.38%	18.75%
2009	34.44%	32.22%	15.00%	10.56%	7.78%
2010	20.30%	49.75%	13.71%	9.64%	6.60%
2011	12.79%	27.91%	15.12%	24.42%	19.77%
2012	21.86%	33.88%	18.03%	10.38%	15.85%
2013	39.20%	32.16%	14.07%	7.04%	7.54%
2014	20.16%	28.40%	18.11%	16.05%	17.28%
2015	15.00%	55.00%	15.00%	10.00%	5.00%

Table 2.2: Academic achievement in the general physics course in Taif University over ten academic years

Score	**Below 60**	**60-69**	**70-79**	**80-89**	**90-100**
Year			**Percentage**		
2006	21.54%	29.92.10%	23.32%	17.98%	7.24%
2007	23.62%	31.96%	19.12%	16.51%	8.80%
2008	16.43%	31.90%	23.52%	18.92%	9.23%
2009	23.85%	32.25%	18.51%	15.14%	10.25%
2010	25.03%	33.77%	21.97%	13.00%	6.23%
2011	21.50%	38.08%	19.38%	12.92%	8.12%
2012	15.32%	45.29%	20.81%	11.60%	6.98%
2013	19.38%	43.51%	18.80%	11.42%	6.89%
2014	21.19%	49.74%	14.99%	9.85%	4.24%
2015	8.14%	50.68%	23.98%	13.57%	3.62%

2.4.3 The STEM Centre for the development of students' skills in science and mathematics

The role of the Centre is to contribute to the development of students' abilities, orientations and tendencies, in order to enhance their choice of future scientific and professional tracks related to STEM. In addition, this centre participates in the study of curricula and provides technical and scientific support to the Curriculum Agency in terms of STEM curriculum development and provides professional growth programmes in cooperation with the National Centre for Educational Professional Development and related bodies in the preparation and development of teachers and practitioners in the field of STEM. Moreover, the Centre aims to promote learning and teaching based on scientific research in partnership with the Excellence Research Centre of Science and Mathematics Education and related bodies to achieve the objectives of STEM and the establishment of activities and events which serve these objectives. The Centre also helps in unifying efforts and liaising between the Ministry of Education and related bodies in the implementation of projects and programmes related to STEM (Tatweer, 2017).

2.4.4 The vision for mathematics and physics in the Kingdom

It is worth bearing in mind that students in the KSA start studying physics from the first-year of secondary school, while general science is taught as a compulsory discipline in all stages of the primary and intermediate stages (Mansour, El-Deghaidy, Alshamrani, & Aldahmash, 2014). The Kingdom of Saudi Arabia has established a vision for mathematics and physics education, which involves developing mathematics and physics research. It is hoped that this will, in turn, create a substantial foundation for other areas of physical science and engineering, provide for the Kingdom's mathematics and physics education requirements, allow for equitable international partnerships and attract the brightest minds into the mathematics and physics fields. The vision concentrates on capacity building in mathematics and physics research, which is undertaken by the King Abdualziz City for Science and Technology (KACST) and universities. An enhanced research capability will support the development of other areas of physical science, computer science and engineering. The short-term vision does not seek excellence in all areas of mathematics and physics but focuses on enhancing capacity for research and education. The

Maths and Physics Program's stated mission, for instance, is to drive research and education excellence in physics and mathematics through a series of initiatives, as highlighted below:

1) undertaking basic and applied research and providing research services
2) driving the enhancement and application of the national mathematics and physics plan
3) bolstering cooperation and communication in the research sector
4) establishing research infrastructure, including major facilities
5) assisting education and training initiatives in mathematics and physics
6) improving public awareness of the contribution of mathematics and physics to technology. (Ministry of Economy and Planning, nd).

As this study was conducted at Taif University in Saudi Arabia, the next section provides some details about this educational institution.

2.5 Taif University

The University of Taif was established in 2003 and is located in the province of Taif in the western part of Saudi Arabia. It has twenty-one colleges, including the College of Science which consists of five departments: Physics, Chemistry, Biology, Mathematics and Biotechnology (Taif University, 2017). Before choosing a speciality, all students undergo a preparatory-year before the first-year of their degree. Therefore, as this study has been conducted with preparatory-year and first-year physics students and teachers, the next two sections give further information about the preparatory-year and first-year physics courses.

2.5.1 Preparatory-year

With regards Taif University, the administration established a preparatory-year in the academic year 2012/2013 in order to ease the transition from secondary school to university. The programme consisted of three streams, which were as follows:

1) the Scientific Stream, which prepared students to enter the colleges of Science, Engineering, Information Technology and Management & Finance
2) the Health Stream, which prepared students to enter the colleges of Medicine, Pharmacy and Medical Sciences

3) the Humanities Stream which prepared the students to enter the colleges of Education, Arts, Sharia and Law.

After graduating from general secondary school, students who sought to complete their higher education joined one of the aforementioned preparatory-year pathways. They had to successfully complete the preparatory-year in one of these pathways as an essential prerequisite to attending one of the colleges at the University. Comparable preparatory-year programmes had been implemented at various universities throughout the Kingdom of Saudi Arabia. The preparatory-year consisted of two terms in the one academic year, and students who were struggling with some courses were allowed to study for a maximum of two additional terms. In order to complete the preparatory-year, students had to obtain an overall grade of 60% for all courses. If a student failed a course more than three times, he/she was automatically excluded from the programme.

According to the Taif University preparatory-year guide, the goals of the preparatory-year were as follows:

1) to develop problem-solving skills and critical thinking
2) to encourage creativity and innovation
3) to build thinking and communication skills and equip students with the necessary skills and knowledge in the English language and information technology
4) to introduce students to the nature of tertiary education before they enrol in a college by preparing them psychologically and academically and giving them the opportunity to determine an appropriate specialization according to their abilities and skills before their orientation to a specific college.

Since the study deals with physics education and seeks to focus on the above-mentioned scientific stream, the preparatory-year and the first-year physics courses of this pathway are presented and illustrated as in the following tables (Taif University, 2014).

Table 2.3: First Term

Name of course	Credits	Prerequisite
English Language Skills (1)	3	--------------
Mathematics (1)	3	---------------
Thinking and Learning Skills	2	-----------------
Information Computer Technology	2	-----------------
General Chemistry	3	-----------------
Islamic Culture (1)	2	-----------------
Total	**15**	

Table 2.4: Second term

Name of course	Credits	Prerequisite
English Language Skills (2)	3	English Language Skills (1)
Mathematics (2)	3	Mathematics (1)
Communication Skills	2	-------------------
General Physics	3	-------------------
Arabic Language (1)	3	------------------
Total	**14**	

It is interesting to note that after completing the data collection for this study, in 2016, Taif University administration announced the cancellation of the preparatory-year, starting from the academic year 2017/2018. Student acceptance would in future be based directly on their chosen major upon completing secondary school, without any preparation year. In future, in order for students to specialise in a scientific discipline, such as physics, chemistry or biology, they should meet the following conditions: (1) students should graduate from secondary school with a minimum average of 40%, (2) they should obtain a score of at least 30% in the General Aptitude Test (GAT), and (3) they should get at least 30% in the Scholastic Achievement Admission Test in science. It is worth bearing in mind that the GAT measures a student's analytical and deductive skills and focuses on testing the student's general capacity for learning regardless of any specific subject or topic. This test measures abilities relevant to: (1) reading comprehension, (2) recognising logical relations, (3) solving problems based on basic mathematical notions, (4) inference skills, (5) measuring capacity. On the other hand, the Scholastic Achievement Admission Test in science covers general and key concepts in biology, chemistry, physics, mathematics and English covered in general secondary schools. Questions vary in their focus on knowledge levels and measure, for instance, comprehension, application or inference skills. Questions cover the subjects in even percentages as follows: biology 20 %, chemistry 20 %, physics 20 %, mathematics 20 %, and English 20 % (National Centre for Assessment, 2018).

As mentioned earlier, in the preparatory-year students took a course in thinking and learning skills. This course consisted of the following areas: (1) learning, (2) learning and memorisation skills, (3) cooperative learning, (4) learning transition, (5) thinking, (6) problem-solving, (7) creative thinking, (8) critical thinking, and (9) development of thinking.

2.5.2 First-year physics degree

The courses of the First-year Physics Degree are presented in the following tables (Taif University, 2014).

Table 2.5: First term

Name of course	**Credits**
Islamic culture (2)	**2**
Calculus (2)	**4**
General Physics (2)	**4**
Electricity and Magnetism	**4**
Programming Languages	**3**
Total	**17**

Table 2.6: Second term

Name of course	**Credits**
Heat and Thermodynamics	4
Differential Equations in Physics	3
Classical Mechanics	3
Vibration and Waves	4
Computer Applications in Physics	3
Total	**17**

This study focused on the general physics course and the mechanics course because the subject of mechanics was taught both in the preparatory-year (in an eight-week section of a sixteen-week course) and in the first-year (as a separate course called classical mechanics); thus, the content of these two courses is presented here.

The topics taught to the preparatory-year students in general physics were: units and dimensions and vector analysis and, in mechanics, uniformly accelerated motion, free fall, Newton's Laws and their applications and work and energy. Students also studied electricity (Coulomb's Law, electric fields, electrical potential, capacitors, direct current circuits) and geometrical optics (reflection and refraction of light, mirrors and lenses, and total internal reflection).

Similarly, the topics of the first-year classical mechanics course were: vector analysis (gradient-divergence-curl), coordinate systems (curvilinear-Cartesian, polar, cylindrical, spherical), motion of a particle in three dimensions, conservative forces and force fields, constrained motion of a particle, central forces and planetary motion, and non-inertial reference frames.

2.6 Summary of the chapter

This chapter has introduced the Saudi context, in general, and the specific context where the current study was conducted. Thus, it has given an overview of Saudi Arabia, its educational system, and the attempts made to develop science education in general and physics education in particular. Finally, some information about the Taif University programmes (preparatory-year and first-year) has been provided to gain a better understanding of the institution where this study was carried out. The next chapter reviews and discusses the relevant literature about thinking and problem-solving and highlights the theoretical framework of the current study.

Chapter Three: Literature Review

3.1 Introduction

This chapter reviews the theoretical framework of this study and the literature in relation to thinking and problem-solving skills. It starts by presenting Piaget's theory as a fundamental theory to develop Vygotsky's theory (Wertsch, 1991), followed by the nature of thinking. After that, why and how thinking skills in physics should be taught are discussed. In addition, transferable thinking skills in teaching and learning are presented. This chapter also discusses problem-solving and the problem-solving phases. Moreover, it focuses on physics and problem-solving skills and also on the factors impacting on problem-solving. Finally, it explains the different types of problems.

3.2 Theoretical framework

This section discusses Vygotsky's theory as a theoretical framework for the current study; however, an introduction into Piaget's theory is a necessary step in order to gain a better understanding of Vygotsky's work.

3.2.1 Cognitive development

Problem-solving skills include a set of steps such as understanding the problem, planning, implementation and evaluation, as suggested by Polya (1957). Following these steps in physics problems eventually leads to cognitive development (Yaseen, 2013) whereby learners can follow a scientific way to reach a desired goal rather than using memory-based or random strategies. In order to comprehend how people, acquire knowledge and develop intellectually, Piaget (1929, 1972) examined children's cognitive development. He carried over his biology background into the study of human learning and attempted to understand how this complex process happens. He developed a theory that can perhaps provide us with a conception as to what happens to learners when they deal with problems and attempt to solve them. Certain problems may be the source of 'cognitive conflict'. For example, if a student is confronted with new physics knowledge or a physics problem that contradicts his or her prior knowledge or with previous experiences or ideas, this will produce a number of questions in the student's mind. However, if the student does not find a solution, a cognitive conflict occurs, which pushes him or her to find a solution to this problem. Piaget divided the stages of cognitive growth into four phases: (1) the sensorimotor phase, extending from birth until age two, (2) the pre-operational phase, from ages two to seven, (3) the concrete operations phase, from ages seven to eleven, and (4) the stage of formal operations (abstract) from eleven onwards.

Moseley, Elliott, Gregson, and Higgins (2005) consider Piaget's theory as having the greatest impact on educational practice and teacher training in the past half century as it clarified the modality of growth stages from childhood to adolescence and how the "understanding of objects, relationships and concepts is limited by their powers of thought" (p.368). Furthermore, King and Kitchener (1994) extended these stages to include university years.

Moreover, according to (Alany, 1987; Al-Khaleely, Haider, & Younis, 1996; Hanfstingl, Benke & Zhang, 2019; Piaget, 1971, 1977; Wadsworth, 1979), four basic concepts determine Piaget's theory: (1) schema, (2) assimilation, (3) accommodation, and (4) equilibration. The notion of schema refers to the way of structuring and categorizing knowledge in the mind in order to understand and interpret the world. For Piaget, individuals are born with general images and schemes which are subject to a continual process of change, which then leads to the formation of new mental compositions. Piaget considered the idea of *schema* as an essential tool for organising units of thought or action that an individual constructs to comprehend connections within a specific environment (Alenezi, 2008). The principle of *assimilation* refers to a cognitive process whereby perception or new conceptual aspects are integrated into an existing schema in the learner. As for *accommodation*, it describes what occurs when learners receive new knowledge that conflicts with what they have in their existing schemata. In this case, the learners change the existing schema or create another one to accommodate the new knowledge. In this stage, previously existent thought is adjusted in the mind based on the educational position which the learner is exposed to in solving problems; this process is called adjustment. If students are introduced to this new way of learning (i.e. problem-solving), it is likely to cause some sort of tensions at the beginning, which can be explained by the notions of 'assimilation' and 'accommodation' as identified by Piaget (1972). As stated by Herron (1978, p.167), "Piaget argues that everyone reverts to concrete operational or pre-operational thought whenever they encounter a new area".

According to Adey and Shayer (2002, p.5), *equilibration* is defined as "the process by which cognitive processing mechanisms in the mind accommodate to events which cannot be readily be assimilated and which create some sort of cognitive conflict", resulting in the correction of the learner's cognitive structure.

Despite the fact that Piaget's thesis can serve as a theoretical framework for education, it has been criticised by some scholars. For example, according to Fox (1993), Piaget views language development as the direct result of cognitive development and it is worth questioning whether the four-stage model accurately reflects the child's actual cognitive development. Moreover, Piaget's formal operational stages do not seem to provide an adequate description of the way most school children think and reason (Bliss, 1995). In addition, for Bruner (1996) Piaget does not seem to consider the importance of children's experiences and context in terms of cognitive development. Likewise, Sutherland (1992) reiterated the fact that Piaget does not seem to take into consideration the children's individual differences in cognitive development which relate to intelligence or personality. "Developmental stages, Piaget's stages in particular, have been also criticized for not explaining why development from one stage to the next occurs, and for overlooking or even ignoring individual differences in cognitive development" (Lourenço, 2016, p.124). Furthermore, unlike Vygotsky who insists on the role of the sociocultural context (Kozulin, 1986), Piaget has been criticised for not paying enough attention to language and the role of social interactions in the child's cognitive development (Bliss, 1995).

According to Cole, Steiner, Scribner, and Souberman (1978), Vygotsky stresses the continuous association between the social and the individual levels in terms of thinking. Hence, this aspect should be taken into account to encourage students to solve physics problems, as the thinking process is influenced by a multitude of social and cultural aspects. The cognitive and mental processes involved in problem-solving, such as thinking and language, become directly influenced by the social and cultural context where students live, in this case, the Saudi society. Therefore, the social and cultural context surrounding students might influence their agency positively or negatively in relation to their own problem-solving ability and their performance towards learning physics. In this regard, “the learner’s agency entails recognition that learning is contingent on the learner’s motivation, consciousness, actions, and interactions with the social, cultural, and physical environment in which learning is taking place” (Jurdak, 2016, p.176). This suggest that a strong or weak sense of agency might emerge through students’ performance in a physics classroom; this performance, as well as their desire to learn, can be affected by social interaction between students and teachers or between students themselves within the physics classroom. Panofsky (2003) claims that, through activities, certain students can demonstrate a strong sense of agency while others may perceive themselves as weak and inadequate learning agents. The latter may even exercise agency by rejecting school activities through an active antagonistic behaviour or a passive disinterest.

Nevertheless, despite the above criticisms in this section, the work of Piaget can be regarded as fundamental in order to comprehend cognitive development. Also, given the preponderance of Vygotsky’s sociocultural theory in thinking, the next section examines this theory in more detail.

3.2.2 Vygotsky’s theory and the cultural context

Sociocultural theory refers to the writings of the Russian psychologist Lev Vygotsky who died in 1934, and “the basic premise of sociocultural theories is that learning is social, and mediated by cultural objects” (Mansour, 2010, p.517). According to Scott and Palincsar (2013):

> The work of socio-cultural theory is to explain how individual mental functioning is related to the cultural, institutional and historical context; hence, the focus of the socio-cultural perspective is on the roles that participation in social interactions and culturally organised activities play in influencing psychological development. (p.1)

This framework provides a wide picture about students’ and teachers’ perceptions of problem-solving in physics in higher education in Saudi Arabia. This, in turn, may further our understanding of the reasons why students face difficulties when dealing with physics problems.

Vygotsky’s sociocultural theory can facilitate the understanding of mental processes (Wertsch, 1991), such as problem-solving, in various cultural or social settings. Indeed, “at the heart of Vygotsky’s theory lies the understanding of human cognition and learning as social and cultural rather than individual phenomena” (Kozulin, Gindis, Ageyev, & Miller, 2003, p.1). Moreover, certain sociocultural aspects provide a deeper understanding of the nature of thinking and the learning process. Indeed, for Vygotsky, “the development processes of everyday concepts and academic concepts are different. Everyday concepts originate in the child’s own life experiences, whereas academic concepts develop during the teaching-learning process” (Haenen, Schrijnemakers, & Stufkens, 2003, p.250).

Moreover, according to Lee and Smagorinsky (2000), Vygotsky’s sociocultural theory is based on four premises. First, for Vygotsky, the process of learning takes place by means of interactions between individuals and their cultural artefacts on the inter-psychological plane. Second, learning that occurs through that inter-psychological plane is referred to as the process of *scaffolding* (Wood, Bruner & Ross, 1976), whereby individuals with more cultural knowledge interact with the less culturally knowledgeable in the form of reciprocal activities that result in the construction of meanings. Therefore, this process of reciprocity is inherent to this activity and not solely a process of transmission from teacher to learner. Third, meanings are historically and culturally constructed, which relates individuals to the cultural history of their daily life. In other words, learning is a social act in which language acts as a fundamental vector, a means of transmission of culture and a meaning construction tool. In this respect, a sociocultural approach can be useful ‘‘to explicate the relationships between human action, on the one hand, and the cultural, institutional, and historical situations in which this action occurs, on the other’’ (Wertsch, Del Rio, & Alvarez, 1995, p. 11). In this regard, it is worth noting here that a fundamental principle of sociocultural theory is the relationship between learning and social interaction and the mediation of cultural artefacts and objects in this relationship (Mansour, 2010), as explained by Wertsch et al. (1995):

> Access to the world occurs only indirectly, or mediately, rather than directly, or immediately. This applies both with regard to how humans obtain information about the world and how they act on it. These two processes are usually viewed as being fundamentally intertwined, mediational means or cultural tools which must play an essential role in the basic formulation of sociocultural research. In particular, they provide the link or bridge between the concrete actions carried out by individuals and groups, on the one hand, and cultural, institutional, and historical settings, on the other. (p.21)

People evolve within a sociocultural environment and are all influenced by both the cultural and social elements that constitute this environment (Wertsch, 1991). In this regard, Vygotsky argued that the context is not an entire entity that has the same impact on every learner, but actually relies on the age and the mental capacity of the learner (Veer, 2007). Finally, Vygotsky insists on the unbounded nature of learning; for him, learning can always occur and is not limited in time or space.

Looking at this problem from a sociocultural lens provides an in-depth understanding of the opportunities for educational reform, in addition to the challenges this may face. Indeed, educational institutions do not exist in isolation from the wider social world; therefore, any suggestion for change or reform at the institutional level must take into account various economic, political, historical, social and cultural factors (John-Steiner & Mahn, 1996).In this regard, Villamil and Guerrero (2019, p.23) emphasised that learning, within this theory, is therefore “also a social phenomenon embedded in specific cultural, historical, and institutional contexts”. This theory assumes that knowledge depends on social and context-specific elements and that it is intertwined with the social context where individuals evolve and interact with each other. These interactions occur at different levels and take different forms and each specific context, such as the school or the home for example, acquires its own norms, language and customs, hence influencing the individuals and their social interactions in its own way (Mansour, 2010).

This study adopts a sociocultural theoretical framework for several reasons. First, this study argues that thinking is influenced by society and occurs within a context of direct or indirect interaction and that the process of thinking is also affected by various contextual elements (Moseley, Elliott, Gregson, & Higgins, 2005). Second, the ability of a student to deal with problem-solving in physics at the university level, whether in the preparatory or first-year, is impacted by all aspects of the sociocultural context of the student. This plays an important role in building the student’s thinking and in grounding it in terms of thinking and dealing with physics problem-solving at university, as students’ beliefs also stem from culture and society. This is because knowledge is built individually and socially (Shehab, 2004) and, as indicated by Alghamdi (2012), the social and cultural context shapes the individual’s thought. Moreover, the aspect of social interaction should be considered as it develops cognitive abilities (Wallace, Bernardelli, Molyneux, & Farrell, 2012). Third, the interaction that occurs in physics lectures between the students and the teacher, or between the students themselves, may contribute to the development of cognitive abilities. In addition, according to sociocultural theory, through this process of interaction and transformation between people and context, individuals change their responses to establish different kinds of meaning (Stevenson, 2004). In this regard, Eun (2019, p.23) indicated:

> The interactions between the participants engaged in a joint activity lead to psychological development as the less competent individual internalizes the interactional patterns. The more competent individual, in turn, develops as well as the interaction also makes the features of activity more conscious and reflective.

Thus, students learn to think about physics problem-solving through the conversation and discussion that occurs within the university community (in the lectures) in order to understand how to solve physics problems. In this regard, Al-Nassar (2011) argues that “learners find meanings not just through individual experiences but also through social interactions” (p. 33). Furthermore, Lee and Smagorinsky (2000) note that the process of learning takes place by means of interactions between individuals themselves and their cultural artefacts on the inter-psychological plane. Fourth, through the process of scaffolding (Wood et al., 1976), which is explained later in this chapter, students learn in a sociocultural context where knowledge and experience are shared among students and teachers in the university setting. In this regard, students share knowledge with their teachers or each other through discussion and conversation and, therefore, this might lead to improving their understanding of concepts which cannot be learnt independently (Aldawahidi, 2006) when dealing with physics problems. Fifth, the present study sought to understand the perceptions of students and teachers with respect to physics problem-solving within the Saudi sociocultural context. In this regard, Schoen (2011, p.18) claims that “sociocultural research necessitates the added dimension of thinking about the phenomenon in a way that sees the big picture of the embedded context in which it occurs”. Sixth, by gaining a greater understanding of “their cultural, historical, and institutional setting” (Mansour, 2010, p.518), the current study looked at this problem from a sociocultural lens to understand the reasons why students faced difficulties that affect their ability to solve physics problems in higher education and how these affect their knowledge and understanding of physics problems. This theory was also used to focus on the nature of the interactions between teachers and their students with respect to solving physics problems.

In addition, Vygotsky emphasised the importance of certain types of interactions between teachers and learners in order to stimulate students' thought, such as thinking aloud, asking questions, or working and learning cooperatively, to help students address complex physics problems, hence the importance of scaffolding (Van de Pol, Volman, & Beishuizen, 2010) as a tool to transform students from dependent to independent learners and enhance their comprehension of physics problems. Moreover, the idea of scaffolding is generally attributed to Wood, Bruner and Ross in their work about the role of tutoring in problem-solving (Wood et al., 1976), and this concept will be explained further in the following section. It is worth mentioning that Vygotsky did not refer to scaffolding in his work, although it is related to, and widely used in, sociocultural theory (Van de Pol et al., 2010).

3.2.3 Scaffolding

Vygotsky's notion of zone of proximal development (ZPD) has been metaphorically described by Wood et al. (1976) using the term *scaffold* to depict the way students are helped by experienced adults in the course of their learning using structured tasks performed in sequential steps to foster cognitive challenge. Scaffolding can be described as a tool used temporarily in order to assist students in coping with either challenging physics problems or complex activities that they might not be able to complete on their own. In this respect, scaffolding can be regarded as closely linked to the notion of ZPD as it relates to the teaching and learning processes of the ZPD (Harland, 2003; Pea, 2004). Vygotsky (as cited in Cole et al., 1978) defined the ZPD as follows:

> The distance between the actual development level as determined by independent problem-solving and the level of potential development as determined through problem-solving under adult guidance or in collaboration with more capable peers. (p.86)

The scaffolding concept relates to the ZPD in terms of:

> The distance between engagement and mastery of a task. It informs how to support learners in their learning or problem-solving progress. […] Scaffolding, then, is a way the teacher (or more able others) can mediate

learning. (McGregor, 2007, p.57)

Moreover, Whipp, Eckman and Kieboom (2005) suggested that assistance provided to students is not aimed merely at directing and assessing them, but rather, it aims to support learners through modelling, feedback, direct instruction, and questioning to allow them to undertake tasks on their own for which they previously needed support.

It is clear that scaffolding plays a role in bridging the gap between learners' current skills and the new skills they want to acquire. More specifically, teachers can use scaffolding with students to address physics problems, bearing in mind the steps involved in problem-solving, including understanding the problem, devising a plan, carrying out the plan and looking back. Also, these steps may assist students and act as scaffolds to bridge the gap between their current skills and what they want to achieve in their learning of physics. In addition, students working in groups or thinking aloud constitute examples of scaffolding (Rosenshine, 1995) to solve problems, insofar as novice students can learn from expert students. This can also enhance students' thinking and, therefore, problem-solving skills in physics. In this regard, Lidz and Gindis (2003) cite Vygotsky in asserting that the ZPD can be affected by the student's capacity to collaborate with experts in order to improve his or her performance beyond his or her initial level without assistance.

Therefore, teachers should encourage their students by equipping them with certain skills or through posing questions to enhance their thinking skills and enable them to reach their desired targets in terms of physics problems. Thus, if teachers do not promote their students' thinking or encourage students' reasoning processes in solving physics problems, this could hinder the use of more effective practices such as scaffolding in the ZPD.

Three types of techniques have been shown to be particularly useful in terms of scaffolding for thinking, including checklist of procedures, process-based questions and graphic organisers (Beyer, 1998).These techniques guide learners through the stages of a particular thinking task by explicitly or implicitly instructing them in the steps they need to follow through, for instance, raising a number of questions that compel students to perform the task in a sequential manner, which constitutes a specific thinking process (Beyer, 1998). With regards scaffolding in the KSA context, tasks and exercises performed in class and through the textbooks used in physics lectures at university may be compared to a checklist of procedures.

Moreover, cueing is another tool that has proved to encourage students to think independently. A cue can be described as a prompt that reminds students of what needs to be done or said without specifically telling them what they should do or say. The idea of cueing thinking consists of prompting the student to use a particular thinking process. Cues are normally far less explicit and direct than scaffolds and their effectiveness is much more dependent on the extent to which students have already internally processed or memorised under that particular cue signal the steps and the rules that set up the task or skill they need to elicit (Beyer, 1998).

Beyer (2008a) suggested four phases with regards to the strategies students and teachers follow in cueing and scaffolding: (1) preview or practice in the skill of thinking, (2) requiring students to implement the thinking skill using a scaffold such as, for instance, a checklist, a graphic organiser or a set of questions related to the skill procedure, (3) requesting students to think about the ways they could apply the thinking skill and finally, (4) asking students to process the topic learned by applying the skill of thinking. Moreover, certain cues appear to be more effective when teaching thinking; for instance, the material used in the classroom, or teachers themselves, can often provide cues such as graphic organisers, checklists or synonyms of skills which have already been covered in previous lessons (Beyer, 1998; Rosenshine, 1995). Also, if university teachers make connections with what students have been taught in physics in secondary school, they can remind and cue their students about what they learned in previous years and what they are learning now in order to refresh and encourage their thinking, especially when they deal with solving physics problems.

Furthermore, interaction between students and teachers encourages students to think and reflect positively on physics problems because the "interaction between teachers and learners is one of the most powerful factors in promoting learning [and] interaction among learners is another" (Angelo, 1993, p.8). In addition, interactive collaborative learning between students in solving problems gives them the opportunity to learn and understand how individuals think differently to overcome difficulties and find solutions, which makes students' thinking explicit. Also, when interaction occurs between teachers and students, it can improve the students' cognitive processes and, therefore, reflect positively on their comprehension (Meloth & Deering, 1999). According to Eun (2019, p.21), "the forms of dialogic interactions, discursive practices, and cultural tools employed by people engaged in collaborative activities, will all be reflected in the individual mental processes". Larkin's (2006) study, emphasised that if students are not given the opportunities to interact with others, this can be a key obstacle to practise or get feedback from others in relation to their own cognitive processing. In this respect, based on Vygotsky's sociocultural theory, knowledge received from a more able or knowledgeable peer provides support to lower ability students through correcting misunderstandings, filling potential gaps in knowledge, reinforcing the links between new and prior knowledge, and enhancing students' problem-solving knowledge and skills (Fawcett & Garton, 2005).

Vygotsky's work stresses the benefits of working with a more knowledgeable expert adult or peer by showing that the expert's actions and thinking become assimilated by the learner through this collaborative process (Jacob, 1999). This indicates that Vygotsky attaches a great importance to the social dimension inherent to the learning process insofar as children are exposed to others' thinking processes, which fosters their reasoning and encourages them to comprehend a question (Nussbaum et al., 2009). Hence, the interaction between students themselves and their teachers through dialogue gives the opportunity for students to develop their thinking and their ideas. In this regard, Wegerif et al. (2010, p.614) report that "in dialogues, voices interact in unpredictable ways to produce new perspectives that enable participants to see the topic of the dialogue in a new way".

Dialogue that occurs within a working group might assist students to communicate with each other and with their teachers, which promotes their thinking (Gillies, 2006; Mercer & Littleton, 2007) and assists them in solving physics problems. According to Wegerif (2002, p.37) dialogue is a "shared enquiry […] informed by more than one voice or perspective". Hence, it is "based on a different kind of relationship between teacher and students, in which students are asked to think, not simply to remember" (Skidmore, 2006, p.504).

In this regard, Mendenhall and Johnson (2010) noted that, if students work in small groups, this might encourage deeper thinking through peer interaction. According to Harskamp and Ding (2006), who conducted an experimental study in Shanghai among secondary school students, collaborative learning, in comparison with individual learning, significantly enhances problem-solving skills in physics. The results of their study showed that students who learnt to solve physics problems in collaboration with others achieved higher test scores than those who learned these skills individually.

In addition, Heller, Keith and Anderson (1992) found that cooperative grouping is an efficient means to teach physics problem-solving. Also, Potter (2014) emphasised that group work can lead to increasing success in problem-solving. Similarly, cooperation between learners may be a factor that positively impacts on problem-solving skills as it is based on the sharing of expertise and knowledge among learners and on approaches facilitating problem-solving. In turn, this enhances the learners' ability to better comprehend a physics problem by deriving from it a series of questions. Nonetheless, certain teachers do not encourage their students to take part in discussions or group work as they tend to focus more on completing their syllabus within the allocated time. This has been noted by Rodrigues (2005), who contends that teachers often complain about the lack of time and flexibility they have to promote students' individual learning and engage in research or other activities. Research points to the importance of dedicating enough time to give students the opportunity to think about their learning (Al-qahtani, 1995; Rodrigues, 2005).

According to Al-Nassar (2011, p.34), "interaction and collaboration could lead to the development of learning", which means that when students attempt to solve physics problems together or when they interact with their teachers, they communicate with each other and get new ideas; this consequently encourages them to learn and solve physics problems. It may be argued that language is also a factor contributing to students' thinking. Indeed, Luangrath and Pettersson's (2012) findings strongly suggest that group discussions are a positive method that encourages students' learning, provides learners with the opportunity to share ideas with their peers and to gain more ideas than through individual problem-solving. Moreover, Heller et al. (1992) found that cooperative grouping is an efficient means to teach physics problem-solving.

In this case, and in the light of sociocultural theory, the interaction between students and their teachers or between students themselves, through for instance dialogue or getting feedback from peers or teachers, could help facilitate students' understanding of what they want to achieve in order to solve physics problems. In addition, because physics consists of abstract terms and difficult words which might not enable students to understand physics easily, connecting their daily lives with physics problems or tasks and also using simple language from their experiences or culture may eliminate the vagueness around their understanding of physics problems. Tao (1999) argues that, by collaborating and cooperating with their peers, learners need to express and articulate their ideas explicitly. Also, as disagreements between students are common, learners are encouraged to justify their stance on a particular problem in order to resolve potential conflictual situations. Finally, during group work, knowledge is co-constructed through the process of sharing ideas. In this respect, according to Vygotsky's theory, this constitutes a great benefit since learning is viewed as related to the process of sharing of meaning and social interaction. By focusing on learners' disagreements, Tao suggests that although the process of co-construction may lead to of erroneous information, conflicts between learners and the resolution of these conflicts always lead to the correct solution of a problem. Also, Alrababah (2017) argues that, if students work together to solve problems through exchanging their ideas and viewpoints, this will facilitate their comprehension of the problem.

According to Cole et al. (1978), Vygotsky mentioned that the child's functional cultural development is affected at two levels: the social level and the individual level. In other words, this development first occurs within society and between people –what Vygotsky calls the "inter-psychological"– and then within the child – "the intra-psychological" (p.57). It can be said that, to some extent, cognitive structures have been built through interaction with others such as teachers, students and the wider social context. Such interactions may encourage students' thinking to a greater extent than individual processes because, when students attempt to work or solve physics problems alone, they may not easily find the solution (Heller et al., 1992). During such interactions in problem-solving, learners may employ a number of significant skills that enhance communication including questioning, explaining, listening or responding. The use of all these skills tends to facilitate the cognitive development of novice and expert learners (Fawcett & Garton, 2005; Johnson-Pynn & Nisbet, 2002). In addition, for Reid and Yang (2002), in order to become successful problem solvers, students ought to learn to cooperate with their peers by discussing together and sharing ideas and experiences and by drawing conclusions together based on available information. In the same vein, when students work as a group, it leads to increasing their success in problem-solving (Potter, 2014). In addition, students can share their knowledge and exchange experiences (Reid & Yang, 2002).

With respect to Vygotsky's theory, Khomais (2007) argued that, in teaching and learning, based on certain cultural differences, a number of predictions can be made as noted in the following quote:

> Vygotsky's socio-cultural theory described how human minds develop in relation to their interactions with their culture in general, which appears to be applicable to all societies, in developed and developing countries. From this point of view, the process of development is the same, but the difference is in the context where the development happens. (p.55)

The students concerned with the present study have different beliefs and backgrounds, which are influenced by their culture as they come from different regions across the KSA. In this regard, when students enter an introductory physics course, they bring with them a generalised set of beliefs regarding the physical world, which is often vaguely based on incorrect empirical evidence, and further rooted in their thought processes. (Martín-Blas, Seidel, & Serrano-Fernández, 2010). Research has demonstrated that students have a limited understanding of physics upon entry to the course, along with predetermined attitudes, beliefs and expectations. These preconceived expectations and beliefs could impact students' learning in the introductory physics course and the way they interpret the knowledge gained in the physics classroom (Sahin, 2010). In this context, Perkins, Adams, Pollock, Finkelstein and Wieman (2005) concluded that students who hold positive beliefs when they come into a course are more likely to have high learning gains.

In addition, the teachers involved with students in the KSA come from different countries such as Egypt, Algeria, Tunisia, Jordan, Palestine and Saudi Arabia. Therefore, the interaction between the culture and background of teachers and students, in addition to the beliefs which are derived from society, might play a vital role in the teaching and learning of physics and in physics problem solving too. Putnam and Borko (2000) argued that "when diverse groups of teachers with different types of knowledge and expertise come together in discourse communities, community members can draw upon and incorporate each other's expertise to create rich conversations and new insights into teaching and learning" (p. 8). As discussed above, Vygotsky's theory was adopted in this study to understand students' problem-solving in physics in higher education within the Saudi societal context. This theory is also addressed later in the Methodology Chapter to explain how analysis and data collection are guided by this theory.

It is worth mentioning here that problem-solving skills are considered as a mental process that relates to cognitive development; hence, it seems helpful to shed light on the nature of thinking, as discussed in the literature review section.

3.3 Literature Review

3.3.1 The Nature of thinking

Thinking is a complex process that includes mental activity, both cognitive and metacognitive; it also has a variety of functions. According to Al-Atoom, Al-Jaragh and Beshara (2007), thinking is a developmental phenomenon that occurs through a series of stages in life, and that is influenced by several factors, such as how the thinker was raised, his or her motivation, abilities or education. In addition, Guttami (2005, p.18-19) states that the variations in people's thinking patterns result from: "(1) differences among individuals in respect of the things they pay attention to, (2) differences in the social circumstances a child is exposed to, (3) differences in experiences and goals, and (4) differences in individual's abilities".

Competing theories of thinking have emerged, incorporating such notions as scientific thinking, creative thinking, and critical thinking. De Bono (1976) expands on this, stating that the variety of thinking levels results in diverse definitions and, therefore, it is not plausible to have only one definition of thinking. However, De Bono views thinking as "the deliberate exploration of experience for a purpose. That purpose may be understanding, decision-making, planning, problem solving, judgement, action and so on" (1976, p.32).

Abojado and Novel (2015) argue that the perspectives of researchers and educators regarding the definition of thinking present different definitions relying on multiple theoretical foundations and orientations. This issue has led to a lack of consensus among researchers in regard to defining thinking, its characteristics, forms and methods.

Furthermore, there is a difference between the notions of thinking and thinking skills. According to Beyer (1988), on the one hand, thinking is a comprehensive course of action, in which “we mentally manipulate sensory input and recalled data to formulate thoughts, reason about, or judge” (p. 72), that is done in order to provide significance to life events. On the other hand, thinking skills are tactics the mind purposefully employs to solve problems and accomplish goals. Whilst Wilson (2000) believes that thinking skills are inconclusively defined, Vail (1990, cited in Owu-Ewie, 2008) contends that they relate to a group of skills, including both basic and advanced skills, which control an individual’s mental process. These skills, according to Vail, involve knowledge, metacognitive and cognitive operations and dispositions. Swartz and Perkins (2017) argue that thinking skills are capabilities that aid some type of thinking.

The use of thinking skills may differ from one culture to another in terms of clarity, understanding the concepts of thinking in the learners’ mind, and of how they apply thinking skills in an appropriate way. For instance, the socialisation and cultural background that individuals acquire during their lifetime influence the way they approach thinking and thinking skills. In this regard, referring to Asian learners, Ng (2001) argues that they show less flexibility than Western learners in dealing with certain thinking skills due to the fact that the latter live in more liberal societies that encourage the use of some elements of thinking; however, Asians tend to live in societies that accord greater importance to the notion of conformity to the social group. Likewise, other scholars such as Craft (2008) and Hongladarom (1999) have pointed to a number of differences between the Asian culture and the Western culture in terms of thinking skills. Western educators who teach in Asian countries have reported facing some difficulties when attempting to teach thinking skills, especially critical thinking (Hongladarom, 1999); however, as noted by Hongladarom (1999), these differences are not very clear.

It is worth bearing in mind that cultural background may play a role in using thinking skills. On the other hand, as pointed by Hongladarom, it could be argued that there are no differences between Asian and Western countries in terms of thinking skills because the structure and nature of humans remains the same regardless of cultural differences. The differences that exist, however, may relate to the way in which thinking skills are applied and the extent to which learners are familiar with them, particularly in Arabic countries where students are often given information to memorise without analysis (Alhodithy, 2009; Alatar, 2004).

The next two sections present why and how thinking skills should be taught, as this is necessary for teachers need to know this in order to encourage students to think and interpret knowledge rather than merely use rote learning

3.3.2 Why should thinking skills be taught?

In general, psychologists and educationists have discussed how and why thinking should be taught and suggested strategies to develop students' abilities and performance in thinking and to enable them to deal with physics problems in an effective way. Towards the beginning of the 20th century, the focus of education was on acquiring fundamental numeracy and literacy skills, such as reading, writing and simple arithmetic, and educational institutions did not pay particular attention to critical thinking or complex problem-solving skills (Zohar & Dori, 2003). The focus, notably reflected in the textbooks, was on the memorisation of facts and students were mainly assessed based on their ability to acquire this information (ibid). As "physics is a fundamental branch of natural sciences that students need to learn for them to appreciate and understand how the natural world behaves" (Crisostomo, 2010, p.165), students should be encouraged to think rather than use rote learning. Moreover, because a fundamental aim of physics as an academic subject is the solving of problems, these types of tasks have become an important part of most physics' classes at various educational levels (Kim & Pak, 2002).

As a result, in recent years there has been growing attention on the teaching and learning of thinking skills; teachers are now being trained to properly guide their students toward gaining such skills and the teaching of thinking has become a growing movement in education with more people supporting its cause (Fisher, 1990). Furthermore, thinking skills in general and problem-solving skills in particular play a crucial role in promoting student achievement and improving classroom instruction to enhance students' capabilities in higher-order thinking. Thus, it seems important for teachers to be provided with training programmes and continuing professional development (CPD) opportunities to improve their practices in the physics classroom. In this regard, Mansour et al. (2014, p.970) showed that "CPD developers should develop learning activities in the CPD programmes that encourage and facilitate teachers to reflect on their learning and practices". Jones' (2008) study showed the correlation between the use of thinking strategies and the length of training received and reported that teachers' practices were largely influenced by the length of their training in thinking.

Higher order thinking refers to a concept related to learning outcomes and thinking based on learning taxonomies, such as Bloom's Taxonomy, that include knowledge, comprehension, application, analysis, synthesis and evaluation (Bloom, 1956). Analysis, synthesis or evaluation are considered as higher-order thinking skills (Zohar & Dori 2003) so students may acquire, analyse and apply thinking skills and then resolve physics problems efficiently using these skills. Beyth-Marom, Novik and Sloan (1987, p.216) claimed that "thinking skills are necessary tools in a society characterized by rapid change, many alternatives of actions, and numerous individual and collective choices and decisions". Physics lessons now aim at engaging students in a process that allows them to develop thinking skills and innovate to resolve the physics problems that they encounter, rather than just providing them with a set amount of information. In turn, students would be likely to make the most of these skills and be ready to make valuable contributions to society's progress (AlSayeh, 1997). Accordingly, it is necessary for educational systems to transition from merely providing information to incorporating the enhancement of thinking skills.

This concept is equally true for developing countries that have been apt to turn to outside sources in order to discover new concepts that will bolster thinking, like the De Bono programme (Al-Gamal, 2001). Shahab (2000) believes that it is going to be difficult for education to prioritise thinking skills; therefore, innovation is required in order to transition from an imitation and repetition culture to an innovation and creation culture; the emphasis needs to change from memorisation to thinking and reasoning.

Likewise, there are some key points that lead us to focus on teaching and learning thinking skills. Firstly, there is a particular relationship between the subject matter knowledge itself – i.e. physics – and the application of thinking skills to acquire this knowledge. Secondly, there is an interdependence between thinking skills instruction and subject matter learning – i.e. physics education. Thirdly, thinking skills are a tool for learning the subject matter and the subject matter acts as a vector for thinking skills. Finally, thinking skills instruction motivates students to acquire these skills because they consider them necessary in order to achieve their learning objectives (Beyer, 2008b).

In this regard, it is important to carefully select appropriate content. Indeed, it is essential to ensure that thinking is involved in the chosen tasks. In this respect, the nature of the subject will determine the selection and implementation of thinking skills which, in turn, affect the knowledge gained by learners. There are, in this regard, fundamental differences in terms of the nature of the problems between scientific and non-scientific disciplines (Mikulak, 2011). In addition, it is important to provide clear instructions to students on why and how to use a complex or unknown thinking skill so as to enhance their motivation. As a result, when learners understand how to employ the skill needed in a particular subject, it becomes far more significant to them (Costa, 2001). Moreover, Beyer (2008b) argues that "instruction in thinking skills in subject matter courses improves subject matter learning as well as the quality of student thinking" (p.229). According to Bransford, Sherwood, Vye and Rieser (1986), many of the current programmes aimed at the teaching of thinking and problem-solving emphasise general skills rather than subject-specific ones. They claim that, by focusing on subject matter knowledge, such programmes can be improved in a way that helps students understand various ways of acquiring new knowledge. In this context, McGregor (2007) confirmed that there is strong evidence that programmes which concentrate on teaching thinking skills can improve students' problem-solving abilities, their academic performance and cognitive processing skills.

Thinking is a fundamental characteristic of human beings that is needed in our everyday lives, but we may encounter complex situations that require higher order thinking skills (Demirel, Derman & Canaran, 2017). These skills can be acquired through practising scientific activities which require reasoning, analysis, classification and observation. These help the student in scientific subjects, hence achieving some of the goals of science education. In addition, the variety of scientific activities urges students to think and solve scientific problems which are related to their daily lives.

The topic of the human mind has received great attention among Islamic scholars who have encouraged people to use thinking in their daily lives. In this regard, Alsenaidi (2012) emphasised that thinking is mentioned in the Holy Quran in different words, such as *meditation*, *mind* (realisation or understanding), *thinking*, *seeing*, *reflective thinking*, *viewing* and *remembering*. Furthermore, Mansour (2011, p.5) mentioned:

> the Qur'an calls for the study of nature not for its own sake, but rather as a means to bring one closer to God. Islam advocates scientific enquiry and encourages the investigation of the universe and its nature as a method to explore the creation of God.

The following verse of the Quran addresses this issue:

> Do they not look at the sky above them? How We have built it and adorned it, and there are no rifts therein? And the earth - We have spread it out, and set thereon mountains standing firm, and caused it to bring forth plants of beauteous kinds (in pairs). An insight and a Reminder for every slave who turns to God. And We send down from the sky blessed water whereby We give growth unto gardens and the grain of crops. And tall palm-trees, with shoots of fruit-stalks, piled one over another. (Quran 50:6-10)

Thus, the Islamic view of exploring natural phenomena encourages scientific reasoning which focuses on the process of knowledge construction using reflective thinking skills (Mansour, 2011).

3.3.3 How should thinking skills be taught?

Students should be instructed in how to utilise thinking skills productively; in other words, thinking skills should be used practically so that they do not remain merely theoretical. Students should be encouraged to use thinking skills while solving physics problems and given the opportunity to apply these skills in their learning through different physics problem activities. In this respect, “teaching thinking skills means, in large part, instructing students in the skill components with which they are unfamiliar and helping them to master their application of these components” (Beyer, 2008a, p.197). Problem-solving has become essential in schools’ educational programmes; thus, curricula need to include appropriate ways to teach thinking skills (Yaseen, 2013). Moseley et al. (2005) contend that a large piece of a curriculum ought to incorporate separate programmes that teach thinking skills, especially ones that promote students' abilities in areas such as strategic thinking, understanding concepts and general thinking skills. Together, schools, teachers and parents ought to aid in creating an environment that promotes thinking skills among the students in order to bolster their thinking during the learning process.

Notwithstanding the above, while researchers agree that thinking skills need to be enhanced, there is dispute as to how this should be done. Whilst Moseley et al. (2005), as aforementioned, believe that there should be comprehensive programmes for teaching thinking skills, others claim that thinking skills should be developed socially in addition to being taught throughout different areas of the curriculum (Burden, 1998). Whilst many tend to believe that thinking skills ought to be taught in school, there has not been agreement as to how this should be accomplished (Kirby & Kuykendall, 1991). Currently, most of the scholarly disagreement centres on whether the teaching of thinking should be a separate programme or integrated into the curriculum. Scholars (e.g. McGuinness, 1999; Swartz & Parks, 1994) have made various suggestions as to how thinking skills should be taught. Some have recommended direct instruction in thinking skills, others have recommended infusing thinking skills into the classroom curriculum, while yet others have suggested integrating thinking into information instruction. The arguments that support each method are presented below.

3.3.3.1 Thinking as a discrete subject

The idea that thinking skills should be taught like any other subject within the curriculum favours a direct-thinking approach where methods that bolster thinking are taught in isolation. Followers of this approach contend that thinking is assessed by the standards of particular subjects (McPeck, 1981) and that each subject has distinct philosophies (Nickerson, 1988) which can be labelled domain-specific. This method of teaching thinking may aid students in utilising suitable reasoning and inquiry skills that apply to each subject, and materials for this method provide guided exercises in administering skills and techniques (Coles, 1993). However, Coles also states that this approach causes tension between teaching thinking and handling direct subjects (Owu-Ewie, 2008), which, according to Joyce (1985), may remove the teaching of thinking from educational plans and thereby diminish its importance so it might tend to get overlooked.

The main drawback of this approach is that teaching thinking as a discrete subject focuses students' attention on thinking skills rather than on the subject itself. In addition, it might necessitate the implementation of introductory classes on thinking in all areas of study, which could eat up both time and budget in a wasteful manner (Owu-Ewie, 2008). Also, it would be challenging to add an extra subject into the course requirements. Wegerif (2007) agrees with this point and stresses that it can be difficult to keep apart teaching a subject and thinking skills in general. However, there are a set of programmes which adopt a discrete approach to the teaching of thinking, such as TRIZ (a Russian acronym which means 'theory of inventive problem-solving') and the Cognitive Research Trust (CoRT). These programmes have been implemented by a number of researchers who noted their positive impact on the students' critical and creative thinking skills and academic achievement (Alharby, 2010; Zamzami, 2004). In Taif University, a course taught in the preparatory year, 'thinking and learning skills', is taught as a discrete subject and delivered to students independently from the physics courses.

Nevertheless, Burke and Williams (2008) have criticised some aspects of the discrete approach that are present in many of its programmes. They claim that many of these programmes do not foster the fundamental skills that can be regarded as effective thinking. This is particularly true if teachers do not have the necessary skills or do not possess a solid background in terms of thinking skills, such as analysis, synthesis or evaluation, to enable them to teach thinking skills to their students.

3.3.3.2 The infusion approach

This approach views the instruction of thinking as a component of all subjects within the curriculum, not as a separate course. The infusion approach has been defined as "integrating thinking skills instruction into the regular curriculum; infused programs are commonly contrasted to separate programs, which teach thinking skills as a curriculum in itself" (Wegerif, 2002, p.37). This approach also contends that a "thinking curriculum" should be implemented to encourage thinking through a "problem-solving approach" that stresses the notions of application and integration of knowledge (Nisbet, 1993). The Thinking Curriculum is based on the idea that learning fundamentally involves thinking, that thinking can be developed within individuals and that educational programmes ought to be redeveloped in a way that integrates thinking into every aspect of students' educational experience regardless of their ages, abilities or disciplines (Resnick & Klopfer, 1989).

In addition, those in favour of the infusion approach claim that thinking cannot and should not be disconnected from its context, which means that such an approach can be integrated into existing practices and that thinking skills can be transferred if they are embedded in teaching and learning (Hu et al., 2011). In addition, Dewey and Bento (2009) concluded that the infusion approach has the potential to impact positively on teachers and learners alike. In this regard, Wegerif (2002) claims that instead of teaching thinking skills through a separate subject, adopting the infusion approach across the curriculum is probably the best way to teach thinking skills.

A negative point about this issue is that if teachers do not have experience, knowledge or awareness of thinking skills, or have a lack of basic knowledge about thinking skills and how to deliver the subject matter, not enough stress will be placed on thinking. Moreover, in this approach teachers should balance thinking skills and subject matter and not concentrate on one side and ignore the other. It can be argued that the infusion approach needs expert teachers to be implemented appropriately across all subjects in the curriculum. In this regard, Brody and Hadar (2015) found that inexperienced teacher educators perceived themselves as novices in terms of teaching thinking while their more experienced colleagues had a spontaneous approach to thinking pedagogy. For Barak and Shakhman (2008), teachers often lack confidence with respect to teaching higher-order thinking skills. This suggests that combining constructivist approaches with the specific steps of thinking pedagogy that encourage the use of higher-order thinking skills is needed in order to integrate such skills in the teaching and learning of science.

In Saudi Arabia, this approach has recently been adopted. For instance, a project called "the Developing Science and Mathematics Curriculum Project" was established between 2009 and 2010 to enhance students' thinking skills through adopting the infusion approach across the curriculum in general and in science and mathematics in particular. It aimed to develop a deeper understanding of the subject matter in all stages of education, including primary, intermediate and secondary schooling.

As the focus on this project relates to science and mathematics, it is worth mentioning here Hurley's (2001) mathematics and science integration theory which suggests five definitions to describe subject integration, from least to greatest level of integration:

> 1. Sequenced. Science and mathematics are planned and taught sequentially, with one preceding the other.
>
> 2. Parallel. Science and mathematics are planned and taught simultaneously through parallel concepts.
>
> 3. Partial. Science and mathematics are taught partially together and partially as separate disciplines in the same classes.
>
> 4. Enhanced. Either science or mathematics is the major discipline of instruction, with the other discipline apparent throughout the instruction. 5. Total. Science and mathematics are taught together in intended equality.

In theory, considering the recent educational reforms in Saudi Arabia to develop the science and mathematics curricula, students are supposed to possess sound foundations from their secondary school education, in terms of thinking skills in general and problem-solving skills in particular. In addition, it is assumed that, throughout the university stage, students can comprehend increasingly complex and intricate scientific knowledge. While the more extensive scientific curriculum is increasingly abstract, it also introduces practical concepts that relate to real life. However, according to Piaget, students at this age have reached the formal operational stage in their cognitive development (Nutta, Bautista, & Butler, 2011); therefore, it is assumed that university students should be able to think about abstract concepts and use thinking skills during this stage to solve physics problems effectively. However, the studies which were conducted in Saudi universities showed that students lacked thinking skills and especially critical thinking skills, as reported in the literature (e.g. Allamnakrah, 2013; Alwehaibi, 2012).

Regarding the aforementioned project "the Developing Science and Mathematics Curriculum Project", Alshaya et al. (2015) conducted a study in Saudi Arabia to evaluate it and concluded that the majority of participating students could be considered as beginners with regards to mathematics, physics and chemistry in many stages of general education. In terms of cognitive domain (knowledge, implementation and thinking), the findings suggested that more than half of the students were at the beginners' level in mathematics and most science specialities. In the above study, scores in the National Center for Assessment in Higher Education examination in 2012 for students taught the experimental curriculum were significantly better than the scores of students who were taught the regular curriculum currently implemented in the Kingdom's schools. Therefore, based on the study's results, the newly developed curriculum was thought to be contributing to improving student achievement.

However, a number of studies have focused on the Saudi physics curriculum in place in schools and have confirmed that the academic achievement of students was weak and that teachers used traditional teaching methods rather than methods that encourage students to develop their thinking (e.g. Alghamdi, 2013; Alghattany, 2013; Alharby, 2010; Alqhatani, 2013; Al-shannag, Tairab, Dodeen, & Abdel-Fattah, 2013; Alswafettah, 2008). In addition, the overall aim of the Science and Mathematics Curricula Development Project was to help students in thinking and problem-solving by paying particular attention to building cognitive capabilities through a variety of exercises and activities included in the curriculum. It is worth bearing in mind that since the physics curriculum in secondary school is based on the Mathematics and Science Development Project, students are supposed to enhance their physics problem-solving skills and thinking skills in general. Through these skills, the project aims to improve the standards of students' knowledge. In addition, when joining university, students are taught a course called 'thinking and learning skills' the aim of which is to enhance students' problem-solving and other thinking skills. Therefore, it is assumed that when the student reaches the first-year of university, he has been well-prepared in the preparatory-year for the steps of problem-solving.

3.3.3.3 The middle ground approach

The middle ground approach can be considered an alternative to the infusion approach, which promotes thinking whilst information is being taught. Through this approach, complex thinking is not taught directly, but learners are still required to think about the subject at hand. This approach seeks to "embed structured thinking skills lessons into a particular curriculum area" (Burke & Williams, 2008, p.105). In the literature, some of the approaches which can be classified as middle ground include CASE (Cognitive Acceleration in Science Education), ARTS (Arts Reasoning and Thinking Skills, Wigan LEA Arts Project) and 'thinking through geography' (Burke & Williams, 2008; Leat,1998).

In the course of an interview with Brandt (1988), Arthur Costa, the editor of Developing Minds, stated that teaching information by itself and believing that students would learn to think during this teaching was a mistake; besides, he explained that teaching thinking skills separately would also be a mistake. Costa, instead, believed that the most effective way was to infuse the two approaches by choosing information for its relationship to the thinking process. Supporters of this middle ground approach argue that the continuous use of thinking, and facing its related challenges, constitute in themselves contributory factors to the enhancement of thinking skills (Beyer, 1997). As a result, students focus on the subject while learning thinking skills. Burke and Williams (2008) clarify the relationship between the middle ground approach and the infusion and discrete approaches: "this approach retains the structure of purely discrete approaches, whilst infusing them (albeit in a more resource-led way) into set curricular areas" (p.105). This approach can be seen as a middle approach between the discrete and the infusion approach.

3.3.4 Transferable thinking skills in teaching and learning

The term transferable can be defined as "taking something, an idea or skill, that has been learnt in one context and applying it in a different context" (Wegerif, 2002, p.37). This raises the question of whether or not thinking skills can be transferred to other subjects. Since the rules relating to curriculum and assessment within the school are strict, transfer may not result from new teaching practices (El-Sawaf, 2007); however, Halpern (1998, p.451) states that teaching through open-ended questions may aid learners in becoming "better thinkers", which is a skill transferable to real-world problem-solving. Still, it is crucial that teachers know how to enhance their own thinking before they can aid their students.

Nevertheless, several authors (e.g. Burke & Williams, 2008; Trickey & Topping, 2004) have supported the idea that holistic and embedded skills (thinking skills that can be applied in different contexts) can be transferred from one situation to another. For Wegerif (2002), "there have been several rigorous surveys of the impact of different teaching methods and programmes in the last decade and these provide convincing evidence for the value of explicitly teaching transferable thinking skills'' (p.20). Furthermore, bolstering investigative skills, forming the ability to come up with questions, and raising self-esteem can also be transferred. Teachers can do this by creating direct links to what students absorb in class and other contexts at the start and end of each activity (Wegerif, 2002).

Moreover, research suggests that the issues students face in terms of the application of these "freshly learned" skills to other situations demonstrates the necessity of teaching to incorporate explicit directions on how to transfer a new thinking skill to a variety of situations (Perkins & Salomon, 1989). Aiding students in becoming skilful thinkers necessitates continual teaching of thinking skills over time and in various situations.

In order to transfer newly acquired skills, it is crucial that learners recognise any likenesses between the original situation and the new one they are encountering so they can more easily recognise when the skill may be useful in other situations (Nickerson, 1989; Perkins & Salomon, 1989). In general, when teachers aid students to employ a skill in a new situation, they ought to make clear the direct principles in order to facilitate the transfer of the skill to these new situations (Perkins & Salomon, 1989).

Research suggests that transfer can be executed even during the initial instruction about the new skill. Teachers, whilst previewing or reviewing a skill, can aid learners in remembering earlier occasions when they tried to utilise the skill and predict future occasions when it would be suitable to utilise that skill again. This process, called "bridging a skill", aids learners in recognising and linking similar markers in contexts where the employment of the same skill would be suitable (Feuerstein, 1983; Perkins & Salomon, 1989).

In addition, it is essential that teaching methods include interaction to encourage students to think effectively. This, in turn, could assist students to transfer thinking skills to solve different physics problems in other contexts. Therefore, when they deal with thinking skills, it is essential that students apply these skills with different issues or physics problems in order to solve these problems. Thus, research needs to focus on problem-solving which includes a number of thinking skills, such as analysis, synthesis, evaluation, understanding the problem and planning. This may encourage students to apply their physics knowledge to solve physics problems, as highlighted in the following section.

3.3.5 Problem-solving

Science teaching involves far more than the mere transmission of facts and information; rather, it aims at achieving a more crucial goal, which is to teach learners to use fundamental scientific concepts or facts in a flexible manner to be able to cope with unexpected situations, to adequately predict effects and solve problems (Reif, Larkin, & Brackett, 1976). The literature provides different definitions of the notion of problem-solving and, therefore, there is no clear definition of this concept (Jerwan, 2012). For example, Malik et al. (2019) defined problem solving as a complex and very significant skill as part of the learning process in all specialties. Some refer to problem-solving as the knowledge gap between individuals and a particular goal they are trying to attain whereby people are faced with a problem and do not know how to bridge this gap in order to achieve a specific objective (Hayes, 1981). Others, such as Gagne (1977), define problem-solving as a thinking process or mental representation whereby learners identify a range of rules, they have previously acquired that can be implemented to solve a new problem. Likewise, problem-solving can be seen as the process of generating learning. Zaitoon (2003) defined problem-solving as a mental representation that consists of a series of steps followed by an individual in order to reach a solution to a problem. Furthermore, it may also refer to the integration of new knowledge with existing knowledge. Yet, when the new knowledge does not correspond to the already established knowledge, the schema, as understood by Piaget, may be reconfigured. Once it has been incorporated, the schema is utilised to form a new schema whereby existing configurations become connected to new ones (McCalla, 2003). When students learn new concepts or new ideas, they might not correspond to what they already know. Hence, students seek to find answers to their questions and then include the newly acquired answers into their own individual schemata.

The proper ways to obtain the answer to an exercise are generally set; therefore, most mathematics textbooks comprise a series of so-called problems. However, in reality, these problems are better described as exercises, as they consist in applying taught techniques to a new set of information in a routine manner. Likewise, most physics and chemistry textbooks' problems are in fact exercises that can be defined as algorithmic problems that require the application of routine procedures in order to find answers (McCalla, as cited in Alqasmi, 2006). For Zewdie (2014), problem-solving refers to "a process that entails the use of high-level cognitive skills, and involves various activities ranging from trial and error, gaining insight and establishing cause-effect relationship" (p.79). Nevertheless, if students know what to do when addressing a problem, this is not a problem anymore but a repetition exercise for what they have learned.

In this study, problem-solving is viewed as a process consisting of a series of steps that include understanding the problem, devising a plan, carrying out the plan and looking back at what has been done to solve the physics problem, that is, the task. Problem-solving is a mental process which requires making students' thinking active rather than static in order to achieve the desired goals of physics learning. Hence, science education should take into account aspects that challenge students' thinking, such as creating different meaningful activities, introducing science topics in a different way, rather than feeding information to students, in order to raise many questions in their minds and therefore, find solutions or answers to these questions. Thus, the focus of science should be on how students use thinking and solving problems to further their understanding of science (physics) instead of memorising without conscious reflection. Solving physics problems requires a set of steps to achieve the desired goals of physics learning.

Several authors (e.g. Abojado & Novel, 2015; Dewey, 1910; Jerwan, 2012; Heller et al., 1992; Polya, 1957; Wallace et al., 2012) mentioned that problem-solving skills consist of a number of steps which assist students to achieve their goals. However, these scholars differ about the steps of the problem-solving process; some suggested four steps (Polya, 1957) whereas others put forward the idea of five (Dewey, 1910; Heller et al., 1992; Jerwan, 2012), seven (Abojado & Novel, 2015) or even eight steps (Wallace et al., 2012). The diversity of problem-solving steps may reflect the fact that scholars consider it crucial to clarify these steps in order to precisely explain what students should do when solving problems. Likewise, these steps of problem-solving constitute a tool that helps students to understand and solve physics problems. For example, Polya (1957) pointed out that the steps of problem-solving are: understanding the problem, devising a plan, carrying out the plan and looking back. According to Polya (1957), regarding the first step (understanding the problem), a set of questions can facilitate the understanding of the problem such as:

> What is the unknown? What are the data? What is the condition? Is it possible to satisfy the condition? Is the condition sufficient to determine the unknown? Or is it insufficient? Or redundant? Or contradictory? Draw a figure. Introduce suitable notation. Separate the various parts of the condition. Can you write them down? (p.xvi)

Regarding the second step (devising a plan), Polya (1957) listed some questions which students should ask when solving a physics problem:

> Have you seen it before? Or have you seen the same problem in a slightly different form? Do you know a related problem? Do you know a theorem that could be useful? Look at the unknown and try to think of familiar problems having the same or a similar unknown. Could you restate the problem? Could you restate it still differently? Go back to definitions. Could you imagine a more accessible related problem? Could you solve a part of the problem? Keep only a part of the condition, drop the other part; how far is the unknown then determined, how can it vary? Could you derive something useful from the data? (p.xvi)

Polya (1957) also suggested further questions related to carrying out the step of carrying out the plan:

Carrying out your plan of the solution, check each step. Can you see clearly that the step is correct? Can you provide that it is correct?” He also mentioned a set of questions in relation to looking back step (examine the solution obtained): “Can you check the result? Can you check the argument? Can you derive the result differently? Can you see it at a glance? Can you use the result, or the method, for some other problem? (p.xvi)

Dewey (1910) suggested five steps to solve problems: “a felt difficulty, definition, suggestion of possible solution, development by reasoning of the bearings of the suggestion and further observation and experiment leading to its acceptance or rejection” (p.72). According to Abojado and Novel (2015), problem-solving includes seven steps which are: feeling a problem, defining the problem, representing and organising information about the problem, creating or selecting a strategy for problem-solving, allocating resources for problem-solving, monitoring problem-solving and evaluating the solution.

Other steps have been suggested in the literature, such as the TASC (Thinking Actively in a Social Context) model. It is a framework developed by Adams and Wallace (as cited in Moseley et al., 2005) to assist teachers and parents in improving primary and secondary students' thinking abilities. This model provides a "practical framework to support problem-solving through the structure of its organising 'wheel' or stages of the process" (Moseley et al., 2005, p.261). The basic idea of the TASC framework is to provide primary and secondary students with a structure that enable them to learn independently or cooperatively by investigating or researching a topic and gain a broader and deeper understanding of how students think and learn. The TASC model consists of a number of steps to solve problems suggested by Wallace et al. (2012, p.61), as follows:

Figure 3.1: The TASC problem-solving 'wheel' (Wallace et al., 2012, p.61).

In light of the aforementioned review of approaches, it can be seen that all of them correspond to these steps, namely, defining the problem in order to understand it and evaluating the process. However, Polya (1957), Abojado and Novel (2015) and Wallace et al. (2012) agree on the step of devising a plan. Regarding the step of “carrying out the plan”, it can be seen that Polya (1957) and Wallace et al. (2012) are in agreement. As mentioned earlier in this section, the diversity of problem-solving steps in these approaches is due to the fact that scholars consider that it is crucial to clarify these steps in order to precisely explain what students should do when solving problems. Also, Polya (1957) and Wallace et al. (2012) mention a set of questions about each step in order to guide learners to solve problems, whereas Abogado and Novel (2015) and Dewey (1910) did not mention any guidance about these steps.

Despite the above-mentioned steps, some scholars believe that possessing knowledge and skills is insufficient to enable students to solve problems (Frazer & Sleet, 1984). In this regard, Frazer and Sleet’s assertion can be questioned as knowledge is a fundamental principle in education, as suggested by Bloom’s (1956) taxonomy of educational objectives, which include knowledge, comprehension, application, analysis, synthesis and evaluation. This taxonomy is arranged in a hierarchical form made of six levels, with knowledge at the lowest and evaluation at the highest level (Moseley et al., 2005). Hence, the other five skills are based on knowledge, which means that this is a requirement to apply other skills such as comprehension, application and analysis. For example, students need to learn physics concepts, facts, physics laws and definitions in order to build a solid theoretical background that may enable them to continue to use other skills such as implementation and evaluation in order to solve problems. In this regard, Ültay (2017) emphasised that problem solving necessitates students to understand conceptually.

The present study sought to measure students’ knowledge of the basic physics concepts in mechanics and their level of problem-solving skills in mechanics in order to understand the students’ readiness to do problem-solving in physics. This is because it is generally accepted that a solid understanding of Newtonian concepts is essential for successful problem-solving (Hestenes et al., 1992). Also, physics teachers at all levels emphasised on the importance of integrating conceptual knowledge with problem solving, as this is a desirable goal in physics education (Docktor, Docktor, Mestre, & Ross, 2015). In the same vein, Eshetu and Assefa (2019) concluded that there is a need to pay more attention to physics concepts used for solving problems in order to enhance students' understanding of physics problems. In addition, problem-solving necessitates understanding, application and evaluation because a learner might not be able to understand a problem if he/she does not have enough knowledge about this problem. Hence, if the learner cannot achieve further understanding of physics problem-solving, it might affect the application skill (carrying out the plan) when solving problems. On the other hand, problem-solving skills are necessary as well as knowledge because these skills are techniques employed to solve problems and accomplish the desired goals of science education purposefully.

According to Smith (2002), "a skill is a capacity, usually acquired through training and experience, to do something well, to perform competently certain tasks" (p.661). Therefore, this indicates that thinking skills can be improved through training or practising (Abojado & Novel, 2015). Likewise, knowledge and skills might be taught and learned, and teachers can assist their students to organise their knowledge. Hence, using techniques such as scaffolding, teachers can encourage students to develop their problem-solving skills. In this respect, Andersen and Nielsen's (2013) claim that teachers can promote students' motivation in several ways, such as teaching through the use of real-life examples to demonstrate scientific concepts, challenging students' thinking through dialogue involving questions and comments to responses, designing assessment which motivates risk taking and supports reflection on mistakes, and assisting students through modelling and scaffolding. Moreover, science content in general, and physics in particular, is relevant to thinking skills which enable students to improve their thinking and therefore to get a deeper understanding, so problem-solving skills will be discussed in relation to physics.

3.3.6 Physics and problem-solving skills

Students need to improve their ability to use thinking skills at a more advanced level, together with their critical thinking skills, which involves the ability to pose relevant questions and use arguments in discussions whilst being able to find a solution to a given problem (Hugerat & Kortam, 2014; Zohar & Dori 2003; Zoller 1993). According to Forawi (2016, p.54), "the science curriculum plays a major role in providing opportunities for students to use and acquire higher-order thinking skills".

Physics can be seen as one of the scientific disciplines that provides students with a plethora of possible activities and tasks, thus, playing a vital role in developing their thinking and their problem-solving skills to gain further understanding of natural phenomena (UK Physical Science Centre, 2008). Moreover, physics requires learners to use their minds in an appropriate way in order to understand a given subject matter or solve a particular problem. Numerous studies have highlighted that physics and chemistry are subjects with which students usually struggle the most (Alsufyani, 2010; Caballero et al., 2012; Farenga & Joyce, 1999; Kim & Pak, 002).

Given the reported difficulties of students with physics and chemistry subjects, it seems evident that there are certain factors contributing to this phenomenon. One of the key factors in this regard is a problem known as cognitive conflict, which Adey (1999) identified as happening when students encounter a problem, they find difficult to accomplish by themselves, but which they can solve or fully comprehend with the help of a more able peer or adult. When learning new physics concepts, students might not make connections to what they already know. Also, students have knowledge but lack understanding of the ways to apply it in physics problems and are thus unable to solve these problems (Zewdie, 2014). This can be explained by the fact that students may often merely memorise knowledge without thinking or because they are not being helped to follow the scientific steps that could guide them to the desired goal, such as, for instance, the problem-solving steps. In this regard, Chi, Bassok, Lewis, Reimann and Glaser (1989) pointed out that weak students are often unable to clarify example exercises to themselves and, in instances where they are able to do so, their clarifications tend to be detached from their comprehension of the principles and concepts in question.

In addition, another factor negatively affecting students' comprehension of physics is the students' excessive reliance on their teachers in the acquisition of new knowledge, which might hinder students' effective thinking. In this respect, Jerwan (2012) warned teachers not to help their students excessively so as to not deprive them of the necessity to use and practise their cognitive abilities and find answers to questions or solve particular tasks. Moreover, teaching methods that do not engage students adequately are not perceived by students as interesting or helpful. In addition, research that has been carried out in Arab countries in relation to thinking suggests that problem-solving skills and critical thinking skills are not used frequently in the classroom and that 85% of the questions posed by teachers are recall questions, whereas questions that are related to understanding, analysing and developing higher order thinking are rare (Abojado & Novel, 2015).

Moreover, traditional teaching methods used in schools and universities in the Saudi context, as reported in the literature (e.g. Alhadlaq, Alabdulkareem, Perkins, Adams, & Wieman, 2009; Alhammad, 2015; Alhodithy, 2009; Alkhowaiter, 2016), might play a role in encouraging students to memorise information or concepts without a deep understanding. Forawi (2016) mentioned that “many of our present education majors have come through systems where the curriculum was more fact-driven, that is, taught using traditional teacher-directed methods” (p.53). Thus, teachers should challenge their students with different levels and types of questioning, such as remembering, understanding, analysing and evaluating, in order to push them to think and assist them in solving physics problems.

In addition, based on the abovementioned issues surrounding the problem of cognitive conflict and given that the development of students’ capacity to think is one of the most important objectives of education in general, there has been a growing interest in teaching thinking skills to overcome the difficulties which face students and encourage them to deal with the problems facing students during teaching and learning science (physics) from different perspectives, for example through Cognitive Acceleration through Science Education (CASE).

CASE represents a widely recognised professional development programme aimed at teachers of science in the UK. A study by Endler and Bond (2008) reported that there has been a substantial amount of empirical evidence supporting the claim that CASE can be of great assistance in terms of developing students’ cognitive abilities, which has a direct, positive impact on their school performance. In addition, Mobbs (2016) conducted a longitudinal study in a UK public school about the effects of the Cognitive Acceleration through Science Education (CASE) programme over two years employing a quasi-experimental design among 19 Year 8 students of various abilities. She concluded that student score gains in examinations indicated an improvement in their cognitive ability, which was particularly true for students with learning disabilities. In addition, Mobbs found that the students with learning disabilities who took part in the Thinking Science programme had improved more in the National Assessment Programme Literacy and Numeracy (NAPLAN) than other students participating in the programme, even the accelerated learners. For Mobbs, this constitutes solid empirical evidence to suggest a correlation between students' participation in a cognitive acceleration programme and the improvement of their scores in standardised tests.

In Saudi Arabia, there have been attempts to apply problem-solving skills with university students in order to find out the extent to which students acquire skills to solve problems. For instance, Aljebally (2013) conducted a study which aimed to identify the level of problem-solving skills among the university's students and the differences between them according to gender, specialisation and academic level and used a test to measure the skill of problem-solving. This test was prepared by the Australian Council of Education Research (ACER) and comprised 45 paragraphs measuring the following skills: ability to analyse and classify data and making generalisations. The test was administered to 2182 students and the results demonstrated that the levels of problem-solving skills for university students were average. The study showed that there were no statistically proven differences between male and female students in problem-solving skills, but that there were statistically proven differences between specialisations and academic levels. The study suggested conducting further studies regarding problem-solving in Saudi Arabian universities.

In addition, Alshaya (2014) conducted a study at King Saud University about the difficulties facing preparatory year students in physics courses through asking faculty members to assess these difficulties and also through analysing students' answers to physics problems in final examinations. He found that the difficulties were related to verbal context, mathematical skills, physical laws, and knowledge of diagrams or graphs.

Moreover, problem-solving in physics might play an essential role in limiting misconceptions in physics in relation to physics concepts or ideas in students' minds that can sometimes be abstract to grasp, such as heat and temperature, energy or Newton's law. According to Yalcin, Altun, Turgut and Aggül (2009), misconceptions are "preconceptions which are in conflict with the scientific view" (p.1083). In this regard, Stein, Larrabee and Barman (2008) emphasised that, compared with other areas of science, physics concepts such as, for instance, motion and force, or physical and chemical changes, seem to be too abstract to understand. Likewise, Gomez-Zwiep (2008) pointed out "misconceptions appear across all areas of science and within all age groups" (p.437).

In addition, many authors (e.g. Abojado & Novel, 2015; Aljabory, 2010; Dogru, 2008; Potter, 2014; Sawafetah, 2008; Tao, 2001; Walsh, 2009; Yaseen, 2013; Zewdie, 2014) discussed the role played by problem-solving skills in facilitating students' learning and their gaining of understanding of scientific concepts in general and physics in particular. In addition, when students apply problem-solving skills, they seem to be active because they build their knowledge following the scientific steps of problem-solving and correct their misconceptions of physics concepts, ideas, laws, principles and the relationships between them. For example, when the concept of pressure is taught, this physical process can be demonstrated in front of the students. This can be done by presenting a cup of water, placing a piece of paper over the cup, then placing the hand on it. After that, the cup is flipped upside down, then we can remove the hand from the piece of paper that over the cup. The students will notice that the water does not escape from the cup and that the piece of paper has retained the water inside the cup, and it has not fallen. So, a number of questions may come to the students' minds: 'what is the reason for the water staying in the cup? Why did the paper not fall from the nozzle of the cup? What is the physics explanation for this phenomenon?' These questions require answers, so students may try to link this problem with what they have learned or with their previous experiences. If they do not find a solution, a cognitive conflict occurs, which pushes them towards finding a solution to this problem. Hence, students may be oriented towards using the steps of problem-solving by their teachers. Using these thinking skills requires the student to 'think smarter' rather than 'struggle harder'; and therefore, may result in long term improvement of their studies. Furthermore, this promotes quality, innovation and excellence in thinking as opposed to merely repeating the words and ideas of others.

However, a question might arise in this regard: why do students have misconceptions about learning science in general and physics in particular? For example, some students confuse the notions of mass and weight or do not know how to use the measurement units of physics like the kg/m^2, kg and ml in an appropriate way. There are several reasons behind this issue. Firstly, students come to class with previous ideas and experiences based on what they have learned in their schools and their daily lives or perceived about natural phenomena. In this regard, when students enter an introductory physics course, they bring with them a generalised set of beliefs regarding the physical world, which is often vaguely based on incorrect empirical evidence, and further rooted in their thought processes (Martín-Blas et al., 2010). Secondly, teachers might introduce physics concepts without giving their students enough time to ponder or ask what these concepts mean. Meanwhile, students may give wrong answers without being corrected by teachers and, therefore, this might create confusion or misconceptions among students about their learning. Unfortunately, the focus during a lecture in higher education is often on learning content and, therefore, students have little time to ask questions or process the information (Forawi, 2016). Thirdly, traditional teaching methods consider the role of the teacher as being central in the teaching and learning process while students are expected to depend on the teacher whose main role is to convey information and knowledge. Ates and Cataloglu (2007) mention that traditional teaching methods do not help students to understand mechanics problems. In this regard, according to Eshetu and Assefa (2019), traditional strategies are not much more effective in helping students solve physics problems.

However, using problem-solving skills may give students the motivation to improve different aspects of their thinking in terms of comprehension, concepts, explaining the physics terminology and meeting other goals of physics education in order to become contributing members of society. Teaching the students thinking skills and problem-solving skills in a systematic, explicit and direct way, whilst teaching them content, might achieve the goals of physics education. For example, if teachers impart these skills whilst having their students participate with the content, the students may do more than master rote memorisation and, instead, learn how to be good thinkers. In this regard, according to Beyer (1997), we can improve the ability of students to think if we can (1) provide thoughtful learning environments, (2) make thinking visible, (3) guide and support student thinking, and (4) integrate instruction in thinking with subject matter.

To improve students' thinking in science in general and physics in particular and encourage them to think, a number of studies have been conducted in Arab countries in relation to problem-solving skills (Albaker, 2012; Aljabory, 2010; Aljebally, 2013; Alshaya,2014; Sawafetah, 2008; Yaseen, 2013). However, these studies have focused on, for example, examining the relationship between problem-solving and academic achievement or creative thinking and deductive thinking. Other studies have investigated the difficulties facing students in physics courses but have not paid enough attention to the perceptions of university students and teachers about students' problem solving in physics and the factors influencing problem-solving success although exploring these perceptions and identiying these factors could help both teachers and students to reach the goals of science education.

Nonetheless, a study conducted in the KSA (Elssbiay & Alshaya, 2018) aimed to identify the most important difficulties facing 11th grade female students in physics problem-solving. The study focused on the verbal structure of the problem, physics laws, basic mathematical skills, and graphics or diagrams. Nevertheless, this study did not pay enough attention to the reasons behind these difficulties. The researchers used a test to explore the difficulties of problem-solving in physics employing a set of criteria to analyse students' answers to physics problems in the final examination.

Also, in the literature at the global level, a number of studies have been conducted in non-Arab countries in relation to problem-solving skills but have not paid enough attention to the perceptions of university students and teachers about students' problem solving in physics. For example, Maries and Singh (2018) sought to investigate the effectiveness of drawing productive diagrams in solving physics problems. Participating students were asked to solve problems in which diagrams were drawn or where the problem explicitly required them to draw a diagram. This study was conducted with students at the University of Pittsburgh in the United States and the researchers developed a rubric to score the problem-solving performance of students. Researchers used think-aloud interviews with nine students. Based on their findings, it was suggested that drawing and employing productive diagrams can improve university students' problem-solving performance, and that students who drew productive diagrams performed better than students who drew unproductive diagrams.

Furthermore, Milbourne and Wiebe (2018) conducted a study to explore the relationship between ill-structured problem solving and physics content knowledge with two groups of high school students with different levels of content knowledge. A talk-aloud procedure was used to narrate students' thought process while solving physics problems. The researchers sought to identify students' solution pathways, and the obstacles that hindered them from reaching reasonable solutions. The study revealed that students with more content knowledge were more successful thereby getting sensible solutions for each of the problems and also faced fewer obstacles. Moreover, these students utilised a greater diversity of solution pathways than those with less content knowledge.

Another study in Indonesia (Gunawan, Harjono, Sahidu and Herayanti, 2017) examined the effect of the use of virtual labs on the problem-solving ability of university students in relation to the concept of electricity. Students were divided into two groups (experimental and control group) and the researchers applied problems solving ability tests. The result confirmed the effectiveness of the use of virtual labs on students' ability to solve physics problems in relation to the concept of electricity. Also, the experimental group had a higher ability to plan and implement problem-solving solutions than the control group.

Moreover, Tms and Sirait (2016) examined the effect of employing multiple representations while learning physics and solving physics problem with first year senior high school students in Indonesia. Students' scores and number of representations used while solving the problems were collected by researchers in order to identify students' representation, analyse students' score and understand the effect of multiple representations. Based on the findings, it was suggested that students who utilised more than one representation such as motion diagrams and force diagrams whilst solving physics problem obtained higher scores than students who did not. Hence, it was concluded that multiple representations can be efficient to foster students' understanding of physics concepts as well as enhance problem solving skills.

Also, Gok (2015) examining the effects of strategic problem solving with peer instruction on college students' performance in physics in Turkey. Students in the treatment group received peer instruction with systematic problem-solving strategies while students in the comparison group received only peer instruction. Data were collected on problem-solving strategies, physics achievement, homework problems, and students' views about the instruction. The study found that the treatment group students changed their perspectives on solving physics problems and that their achievement test performances improved. The researcher also found that the method was beneficial to connect the quantitative solution with concepts.

The current study, therefore, also aims to investigate the factors which affect students' learning of problem-solving in physics as perceived by university teachers and students. Although, as presented in the next section, a few quantitative studies have been conducted globally which have looked at the factors, they have not considered the perceptions of university students and teachers in the wider context in which the students live and interact socially. Therefore, the factors that influence problem-solving success will be set out in the next section.

3.3.7 Some factors impacting on problem-solving success

Understanding the problem is probably a major element in solving any of the problems facing students during learning physics, as explained by Reid and Yang (2002):

> When students work on a problem, the first step is to find and understand the problem. If they do not understand a problem at the beginning, it is impossible for them to solve the problem successfully. Many activities such as imaging, inferencing, decision-making and retrieving of knowledge from memory have frequently been used to help students understand the problem. (p.91)

In theory, in the KSA with the recent educational reforms (the Developing Science and Mathematics Curriculum Project as mentioned earlier), the science curriculum in general and physics in particular contain a variety of activities and exercises that encourage students to apply thinking and problem-solving during their learning. However, through my experience as a physics teacher in general secondary education, and in supervising physics pre-service teachers during initial teacher training, by testing them during physics lessons in secondary schools and teaching pre-service teachers at Taif University, and also through classroom observations of teaching practice, I have noticed that both students and pre-service teachers appear to face difficulties in dealing with higher-order thinking skills, such as analysis, synthesis or evaluation, when they deal with physics problems. It is worth bearing in mind that pre-service teachers in the KSA are university physics graduates, as confirmed by several studies (e.g. Al-Atar, 2004; Al-Oteby, 2008; Alsufyani, 2010).

> With respect to the Middle East, a World Bank study made the following comments about education in the Middle East (World Bank, 1998):
>
> The quality of education defined as learning and achievement is not encouraging [and] education in the [Middle East] region does not effectively impart the higher-order cognitive skills such as flexibility, problem-solving, and judgment needed by workers who will face frequently changing tasks and challenges in increasingly competitive export markets. Instead, the systems teach students how to learn and retain 'answers to fairly fixed questions in problem situations with little or no meaningful context' and thus reward those who are skilled at being passive knowledge recipients. (p.11)

In addition, according to Rugh (2002, p.408), “the quality of Arab education and learning has suffered due to expanding enrolments and falling teacher compensation levels”.

Therefore, a question might be posed here: what are the factors which might affect students’ learning of problem-solving in physics? In order to assist learners, teachers have to pay attention to motivate their learners to overcome any difficulties they might face. Unfortunately, it appears that, according to some research, university physics teaching does not adequately assist students in gaining the necessary knowledge and skills they need in order to successfully deal with problem-solving (Taasoobshirazi & Farley, 2013). In addition, researchers such as Byun et al. (2010) found that certain factors may hinder students’ problem-solving skills in physics. They developed a new framework, for physics problem-solving referred to as the House Model (HM) thereby providing guidance for problem-solving in mechanics. Their objective was to identify the difficulties involved in the process of problem-solving and find an effective way of addressing them. The researchers were able to determine three main factors which caused problems to students in physics problems: (1) an inadequate level of mathematical skills, (2) an insufficient knowledge base in physics, and (3) an inability to fully comprehend the problem they were faced with. Likewise, Ogunleye (2009) found two factors that constitute obstacles for students in solving physics problems: the lack of understanding of the physics problems and the lack of mathematical skills. Moreover, Zewdie (2014) found various reasons why university students are sometimes unable to solve physics-related problems, including the shortcomings of traditional teaching approaches, students' nervousness, little interest in the subject or insufficient knowledge of mathematics. Becerra-Labra, Gras-Martí and Torregrosa (2012) conducted a study about the effects of a problem-based structure of the physics content of a course on students' conceptual learning and problem-solving. It was found that the most problematic issues university students had to deal with in problem-solving were related to an insufficient level of specific skills, such as linking prior knowledge to the new problem situation, performing a qualitative analysis, elaborating a strategy for solving the issue, and performing suitable calculations. Furthermore, Reddy and Panacharoensawad (2017) sought to evaluate student's problem-solving skills and the factors influencing problem-solving difficulties in physics. The researchers used a questionnaire (Likert scale) with 303 undergraduate physics education students in India. The study revealed that poor understanding of the problem and poor mathematical skills constitute obstacles for students in solving physics problems. Nevertheless, the above quantitative studies did not take into account the perceptions of university students and teachers in the wider context although this is an important contributor to the learning process. Hence, there seems to be a lack of clarity regarding how the wider context in which the students live and interact socially may influence their learning of problem-solving in physics in higher education. Consequently, this study also investigates students' basic physics concepts, their problem-solving skills, university teachers' and students' perceptions of the factors affecting students' learning of problem-solving in physics in two different years, together with the sociocultural context. No studies have investigated these aspects together within the sociocultural context although it could lead to a greater understanding of students' problem-solving in physics in higher education in the KSA.

Gabel and Bunce (as cited in Reid & Yang, 2002) reviewed studies on problem-solving in the context of chemistry and suggested that the success of students in problem-solving may be affected by three factors: (1) the nature of the problem itself and its related fundamental concepts, (2) the students' individual differences such as their thinking styles, their developmental levels or their existing knowledge, and (3) the learning context factors, such as problem-solving methods or learning styles.

To make students successful problem-solvers, it is essential that students work as a group and cooperate with their peers in order to share knowledge and exchange experiences (Reid & Yang, 2002). In this regard, Potter (2014) emphasised that group work can lead to increasing success in problem-solving. Moreover, representations are helpful in enabling students to pay more attention to physics concepts and play an essential role in successful problem-solving (Maries, 2013). In the literature, the internal representation refers to the way in which learners process the internal components of the problem in their minds, while the external representation refers to tangible, physical indicators of this information. An internal representation may be a series of words, a figure, a set of information that represents specific components, or an equation that represents the way information is processed in sequential steps in the problem-solving process, such as $pV = nRT$ (Bodner & Domain, 2000), or Speed=distance ÷ time. The main aim of college education in relation to physics learners is to encourage their expertise in physics problem-solving (Taasoobshirazi & Farley, 2013). To achieve this aim, and if teachers want learners to be able to solve problems, it is fundamental to assist them to comprehend basic knowledge and avoid merely developing this knowledge in a rote manner (Reid & Yang, 2002).

Prior knowledge acquired by students and built up in their minds throughout the stages of education prior to joining university is an important aspect in effective problem-solving in physics and it is essential for successful problem-solving, as reported in the literature (e.g. Reid & Yang, 2002).

Likewise, the students' success in problem-solving in the KSA could be related to what is called "continuous evaluation", a concept which the Ministry of Education endorsed in 1997 at the primary level. This assessment method aimed at helping students achieve a level of mastery in different skills throughout the learning process. However, the implementation of continuing evaluation at the primary level has had a negative impact on students in terms of achievement (Al-Sadawi, 2011) with one of the possible reasons for this being that some of the teachers did not possess sufficient knowledge of the goals of continuing evaluation. Perhaps teachers were unable to determine the students' levels of mastery of the skills they were supposed to be gaining during their learning. There was an inability on the part of some teachers to reconcile teaching methods and the method of evaluation, which led to ignoring higher-order thinking skills, as they focused on memorisation. Thus, students had weaknesses in thinking skills such as analysis, comprehension and evaluation, which should be have been developed at the primary stage where students should have been taught to use thinking and problem-solving skills. This has weakened the performance of education in the primary stages and, therefore, led to negative impacts on the subsequent stages – secondary and tertiary education (Almoteary, 2009; Alqurashi, 2011; Al-Sadawi, 2011).

(Al-Sadawi, 2009, cited in Al-Sadawi, 2011) conducted a study in the KSA to find out the impact of applying continuous evaluation on the academic achievement of grade six male primary school students in the KSA. The researcher analysed the teachers' record books and evaluations and claimed that 71% of thinking skills employed by students were focused on the low levels of Bloom's taxonomy. Meanwhile, the levels of understanding and application represented 14%, whereas higher-order thinking skills were omitted in all subject matter.

It should be borne in mind that students who enrol in higher education actually come from the primary, intermediate and secondary levels. This means that we are dealing with students at the tertiary level who might face difficulty in using higher-order thinking skills and, therefore, they may find it difficult to deal with problem-solving because it demands different thinking skills, especially in academic subjects like physics (Wingate, 2007). Likewise, the students may hold incorrect ideas that were not properly constructed in their minds as a result of the prior knowledge they acquired before tertiary education, due to applying "continuous evaluation" with students in primary education in the KSA. Based on the above, problem-solving can be regarded as a complex process that requires careful consideration in order to enhance students' abilities to deal with it successfully (Charles & Lester, 1982). However, problem-solving success might depend on the ease or difficulty of the problem, the amount of information given, and the experience of the students; so, the next section will look at the various types of problems.

3.3.8 Types of problems

Problems can be categorized into eight different types (see Table 3.1) in terms of the amount of data given, the familiarity of the method and the outcomes/goals of the problem.

Table 3.1: Classification of problems

Type	Data	Methods	Outcomes/goals	Skills bonus
1	Given	Familiar	Given	Recall of algorithm
2	Given	Unfamiliar	Given	Looking for parallels to known methods
3	Incomplete	Familiar	Given	Analysis of problems to decide what further data are required
4	Incomplete	Unfamiliar	Given	Weighing up possible methods and deciding on data required
5	Given	Familiar	Open	Decision about appropriate goals; exploration of knowledge networks
6	Given	Unfamiliar	Open	Decision about goals and choice of appropriate methods; exploration of knowledge and technique networks
7	Incomplete	Familiar	Open	Once goals have been specified by the student, they are seen to be incomplete
8	Incomplete	Unfamiliar	Open	Suggestions of goals and methods to get there

Source: Wood & Sleet (cited in Wood, 2006, p.99).

Tsaparlis and Angelopoulos (2000) demonstrated these types of problems so that:

> Types 1 and 2 are the normal problems usually encountered in academic situations. Only type 1 is of the algorithmic nature (exercise). Type 2 can become algorithmic with experience or teaching. Types 3 and 4 are more

> complex, with type 4 requiring very different reasoning from that used in types 1 and 2. Types 5-8 have open outcomes and/or goals and are very demanding. Type 8 is the nearest to real life, everyday problems. (p.132)

This variety of problem types provide useful insights in order to prepare a set of problems for first-year and preparatory-year university physics students at the University of Taif in this study.

For type 3 problems, students need further data to solve the current problem as, for instance, in the following: ‘A spring was elongated by 18cm when a bag of potatoes weighing 56N was hung from its end; calculate the amount of potential energy.’

When the student attempts to solve of this problem, he must determine the known and the unknown, as explained below.

What is known is x=18cm; F=56N.What is unknown is k =? PE=?

So now for the student to find the value of the potential energy, he must determine the value of the spring constant, which is signified by ‘k’. Hence, he/she uses Hooke’s law (F=kx) by examining the previous data, the value of the constant spring (k), as shown below.

k=F/x, and therefore, k= 56N/0.18m= 311.11N/m

Here, the student does not have sufficient information to solve the problem; however, with some thinking and analysis to find this information (the value of the spring constant), he/she can then find the potential energy in the following manner:

$PE=\frac{1}{2}kx^2$; $PE=\frac{1}{2}(310)(0.18)^2= 5.0J$

Moreover, as shown in the Table 3.1, the outcomes and goals of problems (1), (2), (3) and (4) are given, whereas types (5), (6), (7) and (8) are open.

Type 5 is much more open and is left to the judgement of the student as to what would constitute a reasonable answer. For example: ‘Given the formula $[Co(NH_3)4Cl_2]$ deduce from it as much as you can’. This could yield a range of responses, including the oxidation state of the cobalt ion and its electron configuration, the name of the complex ion, its percentage composition, its isomers, its likely reactions, and so on. Type 6 would be similar to type 8 but the given substance would be familiar to the students. Type 7 would require the students to specify the goals, but to achieve these, extra data would have to be requested. Type 8 might be of the kind where the students were given a substance and asked to suggest uses for it. The students would have to ask for, or find out experimentally, its properties before deciding upon uses (Wood, 2006, p.100). This categorisation does not imply any hierarchical classification in terms of difficulty or order, but merely the different types of problems (Potter, 2104).

According to Surif, Ibrahim and Dalim (2014), algorithmic problems do not really measure students' problem-solving skills and abilities; rather, they stress the ability of the students to apply knowledge in a systematic manner. In this regard, I conducted an informal preliminary investigation with three physics university lecturers from the preparatory-year and the first-year at the University of Taif. Several questions were posed to the faculty members by means of email conversations and telephone interviews regarding the nature of the problems facing first-year and preparatory-year physics students at the University. It was found that some students could not deal with different sorts of physics problems and had become accustomed to applying their knowledge in a routine way; this means that students relied on memorisation and using plug and chug ways to solve physics problems. In this regard, Malik et al. (2019) pointed out that students predominantly memorise physics concepts without comprehending. Teachers explained that, for example, if a teacher gave different physics problems by simply changing some figures or by modifying the order of the problem components, students might not address the problems in an appropriate way. In this respect, Dökme and Ünlü (2019) explained that this problem refers to the fact that teachers teach physics principles, concepts and laws, and then solve a few problems related to this subject as a model. Therefore, students can only resolve certain types of problems which have been solved in class by the teachers. Thus, students cannot have sufficient strategies to solve different physics problems. I personally think this can be explained by the fact that students merely memorise the procedures they have learned and try to replicate the same procedures with any physics problems they face without properly thinking. Also, many teachers rely on traditional practices such as assisting students to memorise physics information. A number of studies in the KSA support this assumption (e.g. Alqhatani, 2013; Al-shannag, Tairab, Dodeen, & Abdel-Fattah, 2013). In addition, my professional experience as a physics teacher supports these findings.

With regards to the categorisation of problems, Jonassen (1997) divided problems into two types: well-structured and ill-structured. Table 3.2 illustrates the differences between these two kinds of problems.

Table 3.2: Classification of problems

Well-structured	**Ill-structured**
Present all elements of the problem	Present uncertainty about which concepts, rules, and principles are necessary for the solution or how they are organized
Are presented to learners as well-defined problems with a probable solution (the parameters of problem specified in problem statement)	Possess multiple criteria for evaluating solutions
Engage the application of a limited number of rules and principles that are organized in a predictive and prescriptive arrangement with well-defined, constrained parameters	Offer no general rules or principles for describing or predicting most of the cases
Involve concepts and rules that appear regular and well-structured in a domain of knowledge that also appears well-structured and predictable	Possess relationships between concepts, rules, and principles that are inconsistent between cases
Possess correct, convergent answers	Require learners to make judgments about the problem and defend them
Have a preferred, prescribed solution process	Have no explicit means for determining appropriate action

Source: Jonassen (1997, pp.68-69)

To sum up, students should be acquainted with different types of problems to challenge their thinking in order to reduce the role played by rote learning and to prepare them to deal with higher levels of thinking during their move from secondary school to university. All tests used in the current study, the FCI and the MBT, are composed of multiple-choice items, as shown in the Methodology Chapter. The types of physics problems in these tests can be considered to be ill-structured and belonging to types 3 and 4, according to the aforementioned explanation in Table 3.1.

3.3.9 Summary of the chapter

By reviewing the literature pertaining to the main issues related to this study, it appears that thinking plays an important role in the teaching and learning of physics in general and in physics problem-solving in particular. Also, Vygotsky's theory was adopted in this study to understand students' problem-solving in physics in higher education within the Saudi societal context. The present study seeks to investigate students' problem-solving in physics from a wider perspective within the sociocultural context focusing on several aspects: students' basic physics concepts (using the FCI), students' problem-solving skills (using the MBT) and teachers' and students' perceptions of students' problem-solving in physics in two different years. Therefore, based on the review of the relevant literature, it appears that previous studies conducted globally in the field of problem-solving have not investigated these aspects together within the sociocultural context in general and in higher education in Saudi Arabia in particular. Also, based on the above review in this chapter, I argue that the there is a lack of research highlighting the factors that might encourage or hinder students to learn problem-solving in physics. Although a few researchers globally have conducted quantitative studies about certain factors, they have not taken into account the perceptions of university students and teachers in the wider context where students live and interact socially. Therefore, this study seeks to understand this issue through an in-depth investigation, formulating the following research questions:

1. To what extent does the level of Taif University preparatory-year and first-year students' understanding of basic concepts in mechanics allow them to solve physics problems adequately?
2. What strategies are used by Taif University preparatory-year and first-year students when they deal with physics problems, and why do they use such strategies?
3. What are students' and teachers' perceptions about physics teaching methods?
4. What are students' and teachers' perceptions of the institutional factors impacting on students' learning of problem-solving in physics?

5. What are students’ and teachers’ perceptions of the sociocultural factors impacting on students’ learning of problem-solving in physics?

The next chapter will present the research methodology of the current study.

Chapter Four: Research Methodology

4.1 Introduction

This chapter presents the general approach followed to answer the research questions, which were presented at the end of previous chapter, including the tools of data collection and analysis employed to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. Also, in this chapter, the philosophical assumptions of the study, its research methodology and methods of data collection and analysis are discussed in addition to the ethical issues associated with the conduct of the research. Finally, the chapter highlights the challenges faced throughout the research process.

4.2 Philosophical assumptions of the study

Discussing philosophical assumptions is crucial to determining the nature of any piece of research and to shed light on the researcher's worldviews and paradigmatic and philosophical approaches in undertaking the research. According to Wegerif (2008, p. 359), "there are always theoretical assumptions involved in research determining which phenomena are visible and which are invisible". The term 'research paradigm' was defined by Lynch (2003) as "a lens through which we view the world" (p.2) while Crotty (1998) explains that the concept of paradigm is intrinsically related to two essential philosophical notions, namely ontology and epistemology, which respectively refer to the nature of reality and the ways to know this reality.

Generally speaking, two approaches have emerged with regards to these two concepts in relation to the nature of reality. The first approach views reality as existing independently of the mind while the second conceives reality as constructed through our social interactions (Crotty, 2003). The first approach is often associated with positivism and the scientific paradigm while the other stance is commonly referred to as interpretivism. Followers of the positivist paradigm often conduct research to describe phenomena or explain theories by means of "observation and measurement in order to predict and control forces that surround us" (O'Leary, 2004, p.5). In this regard, Given (2008) defined positivism as "a position in the philosophy of science that emphasizes the importance of observation for the growth of knowledge and thus considers the measurement of phenomena as central to the development of understanding" (p.660). Given (2008, p.660) further summarised a number of criticisms about this paradigm as follows:

- Positivism can be criticized for ruling out various sources of understanding of the world including those deriving from human experiences, reasoning, or interpretation as inappropriate for scientific enquiry. In the social sciences, these sources of understanding (e.g., qualitative interview data) are of great importance as bases for the growth of knowledge, and many areas of social scientific enquiry would be impoverished without recourse to such sources because this interpretative work is itself the subject of interest.
- Positivism ignores context and attempts to establish generalities independent of setting. In social science, setting is often an integral component of activity and as such, cannot be discounted—indeed, claims to knowledge require full contextualization.
- As social order emerges from the sense making of human beings it will be largely contingent upon value-perspectives, and it is problematic to describe a single truth concerning the nature of the social world.
- Positivism is committed to removing subjectivity from knowledge growth and thus denies any role for reflexivity among researchers.

> For these reasons, positivism has been widely criticized since the inception of social science and has been largely replaced with postpositivist epistemologies (theories of knowledge) and ontologies (theories of the nature of reality), particularly in qualitative research. For post-positivists, while the pursuit of knowledge remains an aim of social scientific enquiry, the concept of an absolute truth may be seen as an aspiration rather than as something that can be discovered once and for all. Understanding rather than explanation is sometimes regarded as the objective of postpositivist enquiry, and this objective is often further constrained by acknowledgments of context and contingency. Furthermore, in post-positivism the role of the researcher as interpreter of data is fully acknowledged, as is the importance of reflexivity in research practice (ibid).

Moreover, according to Creswell (2014), "the postpositivist assumptions have represented the traditional form of research, and these assumptions hold true more for quantitative research than qualitative research" (p.7). Also, Creswell (2014, p.7) pointed out that post-positivism recognizes "that we cannot be positive about our claims of knowledge when studying the behavior and actions of humans".

On the other hand, interpretive researchers seek to gain an in-depth understanding of "the subjective world of human experience" (Cohen, Manion, & Morrison, 2011, p.17). Thus, the interpretivist researcher depends on the "participants' views of the situation being studied" (Creswell, 2003, p. 8).

Based on the above premises and the research questions, the current study adopts an interpretive approach, which is justified by the fact that this research cannot be built upon the realist principles that view social reality as existing independently of the knower in order to shed light on the issues under investigation. This research is therefore rooted in the following ontological and epistemological assumptions. First, ontology can be defined as "a system of categories that make up a particular vision of the world" (Grix, 2010, p. 62). Crotty (2010) views that ontology can be seen as the study of being. Moreover, ontological assumptions in an interpretive approach describes the world as a building of many multiple realities reflecting the multiplicity and diversity of individuals (Pring, 2005). Therefore, in terms of its ontological assumptions, the study views the reality of the physics class as a reflection of a multitude of realities constructed by the actors of this reality (students and teachers) through their unique subjectivities and their own accounts of their perceptions of students' problem-solving in physics in higher education in Saudi Arabia. Indeed, this study seeks to investigate perspectives about the phenomenon of problem-solving at the university level within the Saudi social and educational context.

Following the ontological assumptions of the study, it is also crucial to deal with its epistemological stance and how its participants perceive this constructed social reality. As far as epistemology is concerned, Crotty (1998, p.3) defines the term as "a way of understanding and explaining how we know what we know". It can also be seen as "the study of the nature and validity of human knowledge" Wellington (2000, p.196). In this respect, the study does not seek to discover a reality 'out there' but to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. Unlike positivist research that mainly seeks to predict (Grix, 2010) and provide explanations based on causality, this study is not based on pre-set hypotheses about a particular problem. Therefore, epistemologically, this study is not rooted in an objective conception of reality since its main concern is to investigate perceptions, hence, not facts but underlying values (Grix, 2010). Through social interactions, students and teachers build, construct and negotiate this reality together, hence influencing each other's perceptions. This interaction constructs knowledge (Pring, 2005).

It is worth stressing that the study attaches a great importance to the participants' subjective understandings, as well as to their perceptions of what occurs within the context of the physics class with regards to problem-solving skills. Crotty (1998) stresses this point and mentions the importance of conversations in the research approach in order to gain a greater understanding of students' and teachers' perceptions and attitudes. It is therefore essential for the researcher to interact with the participants through a variety of ways, including observations, formal or informal conversations and interpretations, thereby using the researcher's own persona as a tool for data collection and analysis.

In summary, based on the above, and considering the overall objectives of the study, the paradigmatic approach of this research can be broadly described as interpretive and its epistemological nature fits within a constructivist approach which is also characterised by the importance it attaches to the subjectivity of the research participants' perceptions. Moreover, because actions reflect meanings (Weber, 1964), the teaching of physics is seen as a reflection of a great variety of realities constructed by the actors of this social reality; therefore, the role of the participants is crucial in understanding this reality since they are a central element in the social interactions that occur throughout the learning process in physics.

4.3 Research Design: Case Study

Crotty (2003) describes the term methodology as the general design of the research which guides and justifies the use of particular methods based on the researcher's views of reality and knowledge. In addition, the methodology refers to the research approach that describes and provides justification for utilising specific tools for collecting data (Wellington, 2000), which is affected by the paradigmatic approach of a study and its objectives (McMillan & Schumacher, 2014). In this research, a case study approach was adopted.

A case study design was chosen for the following reasons. Firstly, this study deals with a “contemporary phenomenon” (problem-solving in physics) “in depth and within its real-world context” (university physics teachers and students in first and preparatory-years in a Saudi context) “especially when the boundaries between phenomenon and context may not be clearly evident” (Yin, 2014, p.16). Secondly, this design allows the use of multiple sources of evidence (semi-structured interviews, classroom observations and think aloud protocols) to investigate problem-solving in physics within the real-life context (Robson, 2002). Thirdly, “some types of ‘what’ questions are exploratory […]. This type of question is a justifiable rationale for conducting an exploratory study, the goal being to develop pertinent hypotheses and propositions for further inquiry” (Yin, 2014, p.10). This study involved ‘what’ research questions in order to investigate and understand the perceptions of students and teachers regarding problem-solving in physics in higher education in the KSA. Fourthly, Yin (2014) also argues that both the research questions and the research context are crucial in defining the overall approach of a study. For example, when asking questions such as ‘why?’ and ‘how?’ a study focuses on a phenomenon within a precise context and a case study approach is likely to be appropriate. In this study, the question is ‘why?’ and the focus is on contemporary events.

The case study approach has been defined by Yin (2014, p.16) as “an empirical inquiry that investigates a contemporary phenomenon in depth and within its real-world context”. According to Stake (1995), when researchers seek to gain an in-depth understanding of a specific case, the case study approach is generally adopted. Moreover, (Yin 1981-1994, cited in Robson, 2002, p.178), this involves “an empirical investigation of a particular contemporary phenomenon within its real-life context using multiple sources of evidence” as a case study “provides a unique example of real people in real situations, enabling readers to understand ideas more clearly than simply by presenting them with abstract theories or principles” (Cohen et al., 2011, p.289).

This research is based on two cases: (1) preparatory-year students and their teachers represent one case, and (2) first-year students and their teachers constitute the other case. It is worth bearing in mind that this study sought to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives focusing on each case separately. This is because it was thought that preparatory-year students should have gained a solid background from secondary school in thinking skills and problem-solving skills. Likewise, first-year students should have acquired adequate knowledge and skills from secondary school and from the preparatory-year because they are taught a course called ‘‘thinking and learning skills’’. Therefore, each case was observed individually in order to get a deeper understanding of each particular case in relation to students’ problem-solving in physics. Furthermore, in this study, students’ behaviours and classroom management which surround the teaching and learning of physics with respect to problem-solving skills constitute “behaviours [that] cannot be manipulated” (Yin, 2014, p.12); therefore, the case study approach is appropriate in the current study.

4.4 Mixed methods research

This case study research used a mixed methods approach employing quantitative and qualitative methods of data collection (interviews, classroom observations, think aloud protocols and quantitative tests) to get a greater understanding of the research problem. Indeed, rather than only using either quantitative or qualitative tools, “mixed methods research is a good design to use if you seek to build on the strengths of both quantitative and qualitative data” (Creswell, 2012, p.535). In this respect, Cohen et al. (2011, p.26) argue that mixed methods “is a way of thinking, in which researchers have to see the world as integrated and in which they have to approach research from a standpoint of integrated purposes and research questions”. Furthermore, conducting mixed methods studies allows researchers to tackle more complex issues and gather richer information about their topic of investigation than in studies involving only a single instrument (Yin, 2014).

In the current study, a mixed methods approach was adopted in order to investigate the phenomenon of problem-solving in the Saudi context using different tools to obtain a clear picture about this issue and understand the reasons that might prevent university students from using thinking skills and dealing effectively with problem-solving in physics. In addition, because the quantitative results obtained from the FCI and MBT questionnaires (see Table 5.1) did not provide enough evidence of students’ problem-solving abilities in physics and the reasons which might prevent them from using problem-solving skills effectively in their learning, I needed, through qualitative methods, to engage with students of both years in in-depth discussions about their difficulties about solving physics problems. Therefore, this study used qualitative follow-up procedures to gain a deeper understanding of students' problem-solving in physics.

I selected students to be interviewed to understand their difficulties in problem-solving. Most specifically, I needed to investigate why most students scored below 60% and why their understanding of Newtonian concepts seemed far too limited for successful problem-solving. Therefore, I sought to question whether the pedagogy adopted in teaching and learning physics was the cause or whether students entered the university with very limited basic knowledge and skills in terms of physics concepts.

Finally, it was important to investigate the impact of society and culture in this issue. The classroom observations were used to investigate the dynamics of the physics classrooms and the teaching methods used to assist students in solving physics problems. Moreover, classroom observations were used in this study as a supporting tool for clarity or for emphasis on issues raised during the interviews. Also, the current study used think aloud protocols in order to gain an understanding of how preparatory and first-year students solved a mechanics problem.

According to Bryman (2016), Creswell (2012) and Creswell and Clark (2011), there are six mixed methods designs: the convergent parallel design, the explanatory sequential design, the exploratory sequential design, the embedded design, the transformative design, and the multiphase design, as shown in Figure 4.1 below. While the first four designs can be regarded as basic designs commonly adopted in research nowadays, the transformative design and the multiphase design are now becoming more and more popular among researchers.

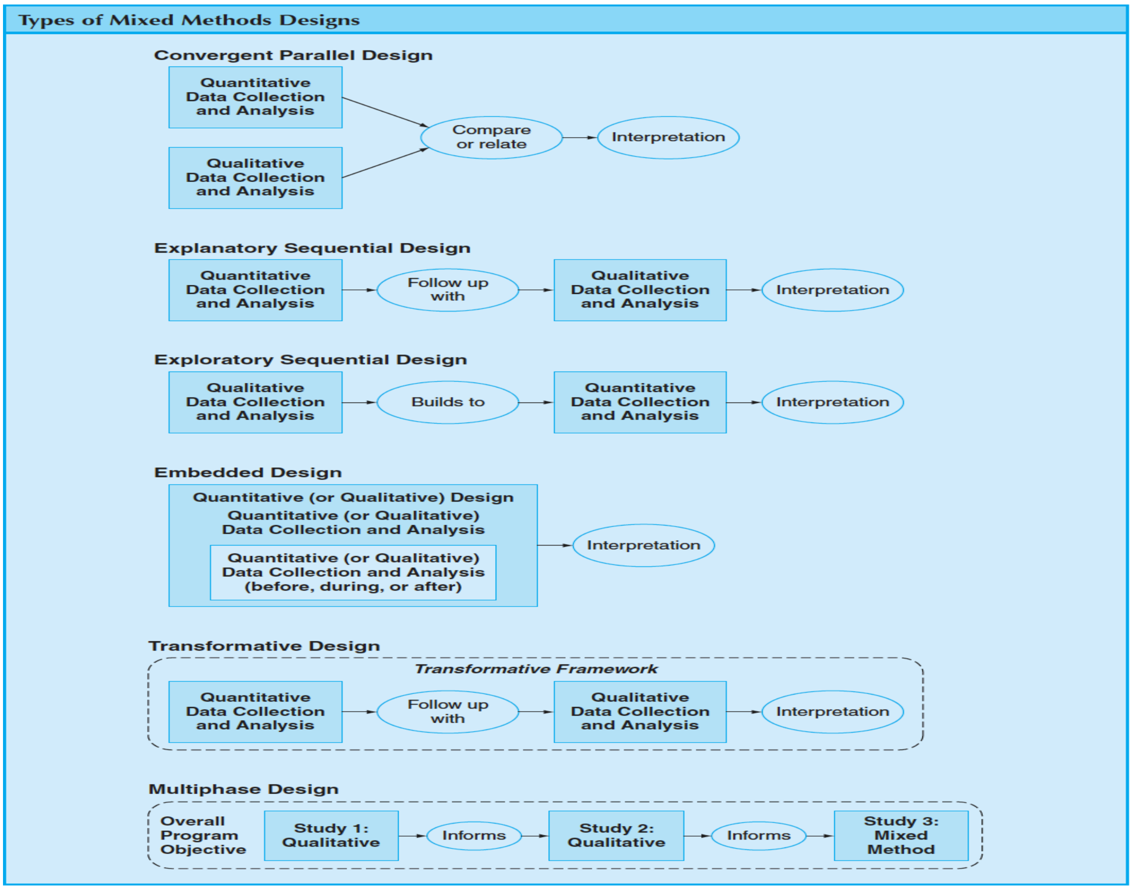

Figure 4.1: Types of mixed methods designs (diagram adapted from Creswell, 2012)

This study adopted an explanatory, sequential mixed-methods approach, as shown in Figure 4.2 below. The data were firstly collected quantitatively to yield initial results and to allow me to gain a broad idea of the research problem. Following this, qualitative data were collected to give focus and depth to the explanations of the previous bigger picture (Creswell, 2012). With respect the choice of the sequential design, Creswell (2012) explains, however, that one of its challenges is that researchers need to make the right choices with regards the quantitative results that need further in-depth investigation, which also involves choices in terms of participant selection and research questions. In addition, it has been argued that this type of design is time consuming and demands a certain level of knowledge and skill in both qualitative and quantitative research designs. Nevertheless, quantitative and qualitative methods were employed in this research in order to answer the research questions. The next section sheds light on the sampling strategy adopted in this research.

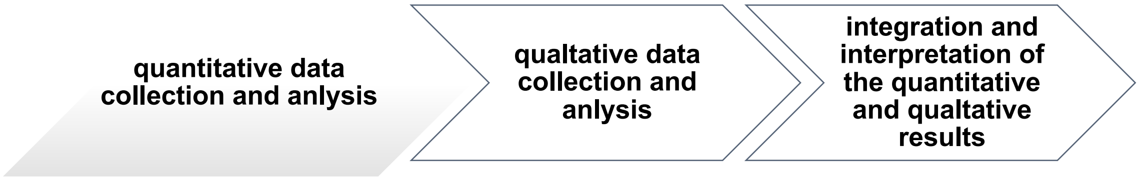

Figure 4.2: An explanatory sequential mixed methods approach used in the current study

4.5 Sampling

4.5.1 Questionnaire respondents

This study was conducted in Taif University for several reasons. First, I live in Taif city and am a lecturer in science education in Taif University. In addition, the Physics Department of the University were welcoming and very helpful in facilitating the research process. Because in quantitative inquiry “the focus is on random sampling”, choosing representative individuals and then generalising the data (Creswell, 2012, p.206), systematic random sampling was used for the quantitative methods in order to select participants who would “be representative of the population” (Creswell, 2012, p.143). According to Kemper, Stringfield and Teddlie (2003, p.278) “systematic random sampling techniques involve selecting every n^{th} unit of the target population from a randomly ordered list of the population”. Therefore, each fourth preparatory-year student from the register was chosen to complete the questionnaires (FCI and MBT). As a result, 488 questionnaires were distributed among preparatory-year students and 413 questionnaires were received. Thus, the total sample for the preparatory-year consisted of 413 students aged between 18 and 19 years.

On the other hand, first-year students were chosen using convenience sampling (Creswell, 2012) as there were fewer of them to choose among, there being only two available classes. The third class of first-year students, which consisted of 23 students, as mentioned in the pilot study section, had been used to pilot the two questionnaires and was, therefore, not included in the main study. As a result, the total number of questionnaires received from first-year students was 95 (n=95) out of 108 questionnaires initially distributed.

Participating students in the first-year were aged between 18 and 21 years. Therefore, the total number of questionnaires received was 508 for both years, while initially a total of 596 questionnaires were distributed, which means that the response rate was 85%.

However, it is worth bearing in mind that some students did not complete all the questions on the FCI and MBT tests at the two levels (preparatory and first-year). This was because some of them were absent when the MBT test was distributed, and some students chose more than one answer per question on the tests. As a result, 37 preparatory-year students and 13 first-year students were excluded from the FCI and MBT questionnaires, which means that the total number of discarded questionnaires from both years was 50. Therefore 376 questionnaires were completed by preparatory-year students and 82 by first-year students. The following table provides more details about the sample.

Table 4.1: Size of the sample for the FCI and MBT questionnaires

	Preparatory-year			**First-year**		
questionnaire	**Total number of questionnaires**	**Missing cases**	**Total number of valid questionnaires**	**Total number of questionnaires**	**Missing cases**	**Total number of valid questionnaires**
FCI	413	37	376	95	13	82
MBT	413	37	376	95	13	82

4.5.2 Interviews and think aloud protocol participants

Because, in qualitative research “the intent is not to generalize to a population, but to develop an in-depth exploration of a central phenomenon” (Creswell, 2012, p.206), for the qualitative data, students and teachers were purposefully selected, which is the most popular strategy in relation to qualitative research (Hoepfl, 1997). This strategy was used in order to get a variety of perceptions from students about physics problem-solving. In addition, maximal variation sampling was used whereby “diverse individuals [were] chosen who are expected to hold different perspectives on the central phenomenon” (Creswell & Clark, 2011, p.174). Participants were chosen based on certain characteristics described by their teachers such as their different achievement levels, their ability to express their perceptions and ideas easily, and their desire and enthusiasm to participate.

4.5.2.1 Students

For this research, after completing the questionnaires, the participating students were asked to provide their contact details if they wanted to take part in an interview. In this respect, the questionnaire was useful to select participants for the qualitative methods. This study used qualitative follow-up procedures to gain a deeper understanding of students' problem-solving difficulties in physics. Initially, a total of 48 students from both of the year groups left their details. I then asked their teachers to select students from these based on characteristics such as their achievement level, ability to express their perceptions and ideas, and their desire to participate, as it was thought that the teachers would be knowledgeable about their own students. Consequently, the teachers chose 35 students. Those students were then contacted by phone to ensure that they were still interested in taking part in the interview. Some of them wished to withdraw at this stage, while others did not respond to my calls. As a result, 21 students agreed to participate in the interview. For the think aloud protocols, at the end of interviews students were asked if they would like to take part in a think aloud protocol. All interviewees agreed to participate, so the total number was 21, made up of ten preparatory-year and eleven first-year students, for the interviews and think aloud protocols.

4.5.2.2 Teachers

All first-year teachers took part in the study (two teachers) in addition to three teachers who had previously taught first-year mechanics and wished to participate. Therefore, five teachers in total were interviewed for the first-year. Moreover, four preparatory-year teachers were interviewed, as well as one teacher who had previously taught in preparatory-year and wished to be one of my participants.

4.5.3 Classroom observation sample

The preparatory-year classrooms for observation were chosen purposively, based on the teachers' recommendations, and therefore four preparatory-year physics classes were observed. Classroom observations in the first-year were chosen using convenience sampling (Creswell, 2012) as there were only two classes and also because the teachers in these two classes welcomed the conduct of observations. Having explained the sampling and participant selection strategies, the next section will shed light on the data collection methods.

4.6 Data collection methods

According to Cohen et al. (2011), the researcher’s choice of a particular tool for collecting data can best be justified by its effectiveness in answering the research questions. The study sought to quantitatively measure the students’ levels of problem-solving skills and their understanding of basic physics concepts in order to understand the students’ readiness to do problem-solving in physics. In addition, the study aimed to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. The data collection methods in this study were questionnaires, interviews, think aloud protocols and classroom observations. In this study, these methods are related to the theoretical framework and research questions, as they give a wider picture of students’ problem-solving in physics in higher education within the Saudi context where students live and interact socially. The following table summarises how the instruments and samples are related to the research questions.

Instruments	Sampling/participants	Research questions
Questionnaire FCI, MBT test	376 preparatory-year students 82 first-year students	To what extent does the level of Taif University preparatory-year and first-year students' understanding of the basic concepts in mechanics allow them to solve physics problems adequately?
Think aloud protocols and interviews	10 preparatory-year students 11 first-year students	What strategies are used by Taif University preparatory-year and first-year students when they deal with physics problems, and why do they use such strategies?
Interviews and observations	10 preparatory-year students, 11 first-year students, 5 preparatory-year teachers, 5 first-year teachers	What are students' and teachers' perceptions about physics teaching methods?
		What are students' and teachers' perceptions of the institutional factors impacting on students' learning of problem-solving in physics?
		What are students' and teachers' perceptions of the socio-cultural factors impacting on students' learning of problem-solving in physics?

Table 4.2: Instruments of data collection, sampling, participants and research questions.

The data collection methods (questionnaires, interviews, think aloud protocols and classroom observations) are presented in the following sections.

4.6.1 Questionnaires

In order to understand the students' readiness to do problem-solving in physics, in this section, two questionnaires were used to collect data: (1) the FCI (see Appendix 5), and (2) the MBT (see Appendix 6). These questionnaires are presented in the following sections.

4.6.1.1 The Force Concept Inventory questionnaire

In light of problem-solving skills issues in higher education in physics, a number of researchers (e.g. Byun & Lee, 2014; Gok, 2014; Kozhevnikov, Motes, & Hegarty, 2007; Maries, 2013; Mualem & Eylon, 2010; Sahin, 2010; Scott, Gray, & Yates, 2013) developed the FCI test, studying the issue of problem-solving in the subject of mechanics and Newtonian physics. This test is probably the most frequently used instrument of its kind (Hestenes & Halloun, 1995; Hestenes et al., 1992). This test comprises 30 tasks designed to examine knowledge of the concepts of force and motion (Sahin, 2010) and consists of six conceptual dimensions (Hestenes et al., 1992) as shown in Table 4.3.

Table 4.3: Newtonian Concepts in the FCI

Dimensions	Inventory item
1. **Kinematics**	
Velocity discriminated from position	20
Acceleration discriminated from velocity	21
Constant acceleration entails parabolic orbit	23, 24
Changing speed	25
Vector addition of velocities	7
2. **First law**	
With one force	4, (6), 10
Velocity direction constant	26
Speed constant with cancelling forces	8, 27, 18, 28
3. **Second law**	
Impulsive force	6, 7
Constant force implies constant acceleration	24, 25
4. **Third law**	
for impulsive forces	2, 11
for continuous forces	13, 14
5. **Superposition principle**	
Vector sum	19
Cancelling forces	9, 18, 28
6. **Kinds of forces**	
Solid contact	
Passive	9, 12
Impulsive	15
Friction opposes motion	29
Fluid contact	
Air resistance	22
Buoyant (air pressure)	12
Gravitation	5, 9, 12, 17, 18, 22
Acceleration independent of weight parabolic trajectory	1, 3, 16, 23

The FCI test is available in Arabic at the Modeling Instruction Program at Arizona State University (Modeling.asu.edu, 2018). It has been translated by the Excellence Centre of Science and Mathematics Education at King Saud University in Saudi Arabia (2011). I personally contacted David Koch, from the Modeling Instruction Program at Arizona State University in order to request permission to download the Arabic FCI version from their website because this version is protected, and a password is required.

In the present study, the FCI test was used for the following reasons. First, the FCI can be used to evaluate students' comprehension of the fundamental concepts in mechanics. Second, there is significant evidence that supports the idea of a close correlation between the FCI score and various Newtonian skills like problem-solving (Ates & Cataloglu, 2007; Hestenes & Halloun, 1995; Hestenes et al. 1992). Third, the subject of mechanics is being taught both in the preparatory year (in an eight-week section of a sixteen-week course) and in the first-year (as a separate course called classical mechanics) at Taif University. Fourth, mechanics is a substantial subject in physics and its importance is the reason why several researchers have examined the issue of problem-solving in subjects related to it (Byun et al., 2010).

4.6.1.2 The Mechanics Baseline Test

The Mechanics Baseline Test (MBT) was used to quantitatively assess students' problem-solving skills in relation to basic concepts in mechanics (Ates & Cataloglu, 2007). As shown in Table 4.4, this test is composed of 26 multiple-choice items spread over three categories (Hestenes et al., 1992) used to evaluate students' ability to relate fundamental mechanics concepts with problem-solving.

Table 4.4: Newtonian concepts in the Mechanics Baseline Test.

Category	Question
A. Kinematics	
Linear motion	
Constant acceleration	1, (2), (3)
Average acceleration	(18), (23)
Average velocity	25
Integrated displacement	24
Curvilinear motion	
Tangential acceleration	4
Normal acceleration	5, (8), (12)
$a = v^2/r$	(9), (12)
B. General principles	
First law	(2)
Second law	(3), 8, (9), (12), (18)
Dependence on mass	17, 21
Third law	(12), (13), 14
Superposition principle	7, (5), (13), 19
Work-energy	20
Energy conservation	10, 11
Impulse-momentum	16, 22
Momentum conservation	15
C. Specific forces	
Gravitational free- fall	6, 26
Friction	(9)

Note: Each concept is involved in the corresponding question. A parenthesis means that other components are significantly involved in the question.

In this study, the quantitative methods were implemented over a period of four weeks, as explained in Table 4.5 below. This allowed me to reflect on a number of issues that emerged based on these initial results. For example, based on the quantitative results obtained, first-year and preparatory-year students were asked during interviews about the difficulties they encountered in completing the FCI and MBT tests, how they dealt with unfamiliar problems, and why they thought they were unable to deal with unfamiliar physics problems.

Table 4.5: Schedule for distributing the two tests

Week	Date	Test	First/preparatory-year
1	Preparation		
2	28/2-3/3/2016	FCI	✓
3	6-10/3/2016	MBT	✓
4 & 5	11/3/2016 to 2/4/2016	Quantitative Analysis (descriptive analysis)	✓ ✓

4.6.2 Interviews

In this research, interviews were used to gain insight into the research questions (RQ2, 3, 4 and 5) and investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. Interviews are useful because they allow researchers to gain rich data by complementing information from other instruments while giving the opportunity to all respondents to express themselves based on their individual contexts (Radnor, 2002).

The use of face-to-face interviews can be justified by the desire to interact with participants, gain insight into their experiences with regards problem-solving skills, understand what impacts on their perceptions, and hear participants' expression of their personal views and opinions. Interviews allow exchange of views between participants and researchers on a particular issue while providing flexibility in collecting data (Cohen et al., 2011). Interviews can be defined as an encounter between two individuals "to exchange information and ideas through questions and responses, resulting in communication and joint construction of meaning about a particular topic" (Janesick, 2011, p.100).

In this study, semi-structured interviews were used to grant the researcher more control over the interview than in unstructured interviews (Wellington, 2000). The interview schedules were designed in the light of the literature (e.g. Alsenaidi, 2012; Byun et al., 2010; Gok, 2014; Maries, 2013; Ornek, 2009; Potter, 2014), and modified by several experts in the field, such as my supervisor, several PhD students and academic staff. Two interview schedules were designed: one for students of both years (see Appendix 7) and one for teachers of both years (see Appendix 8).

The interview brought a number of valuable benefits such as, for instance, the ability to maintain a certain flow during the conversation, to ask additional questions and probe the respondent's answers while remaining focused on the topic of discussion.

Interpretive research mainly utilises interviews to gather the perceptions of participants. According to Rapely (2001), interviews can be regarded as a process of social interaction specifically designed to extract relevant views from participants. For this reason, it is crucial for researchers to establish good rapport with their participants by demonstrating flexibility and ability to adapt to the participants' specific contexts. This is partly why "semi-structured and unstructured interviews are widely used in flexible, qualitative designs" (Robson, 2002, p.271). Also, Radnor (2002) points out that semi-structured interviews are helpful to maintain a pleasant dialogue and allow researchers to raise particular questions at the appropriate moment to guarantee a certain coherence in the structure of the interview. Also, this flexibility allowed me to cover some social aspects in the light of the sociocultural theory.

Yin (2014) explained that one of the main strengths of the interview is that it highlights participants' explanations, opinions, personal views, attitudes and perceptions as well as the meanings they attribute to reality. Thus, interviews allow respondents to express themselves and provide researchers with description of the participants' perceived realities (Kvale, 2007).

Nonetheless, the use of interviews entails additional concerns, predominantly based on the character of the interaction between the researcher and the participants insofar as too close a relationship between could be problematic. As a practical example, Yee and Andrews (2006) warn that participants might inquire about the researcher's opinion on a pertinent matter prior to the interview, which might significantly affect their answers. Furthermore, if open questions are used, participants might not feel comfortable answering them, which can subsequently create a negative atmosphere, which might not be very effective as they open the door for broad, vague answers or answers with too many irrelevant details. Besides, although this can be quite problematic for a large number of inexperienced researchers, the use of prompts and probes is extremely important in order to give participants the opportunity to articulate their responses and fully express their views. Therefore, researchers should conduct interviews in a stimulating way in order to enable respondents to clarify their answers instead of swiftly moving from one question to the next. In the present study, the participants were presented in advance with an idea of what the interview would cover and were encouraged to express their opinions on problem-solving skills.

4.6.3 Think aloud protocols

Various studies in education have used think aloud protocols in order to investigate how students use problem-solving processes when they are given a task to solve (e.g. Ali, Abd-Talib, Ibrahim, Surif, & Abdullah, 2016; Atman & Bursic, 1998; Duffy, Sorby, Nozaki, & Bowe, 2016; Rose, Carter, Brown, & Shumway, 2017). The following quote is an extract of a think aloud with one student:

> Firstly, I have a box on a tilted surface, mmm... let's assume that this tilted surface and this box sits at an angle of 30 degrees and the weight... mmm is 562 Newton. Okay, I'm going to take the weight and multiply it by the sine of the angle 30, ahh... the result mmm... is 281 N. Okay, mmm… then I will find the perpendicular axis… ahh... I think with the perpendicular axis… mmm, I will take the weight and multiply it by the cosine of the angle 30 and, ahh…the result mmm... is 486.71 N.

The current study used think aloud protocols (see Appendix 10) in order to understand how preparatory- and first-year students solved the mechanics problem which was given to them.

Leighton (2017) provides guidance for researchers wishing to employ think aloud protocols to investigate problem-solving. For instance, he recommends making sure that the think aloud is really based on problem-solving tasks and that it requires monitoring based on the level and ability of participants. In my study, the following mechanics problem was given to the interviewees:

> A box weighs 562 Newton on a tilted surface at a 30-degree angle. The force of gravity has two components, one perpendicular and one parallel to the incline. Find the two components of the weight force.

According to Leighton, it is also essential to identify and adopt a cognitive framework established from research to be used with the targeted participants. Then, based on this framework, the researcher should be able to determine possible problems and challenges faced by participants in completing the chosen tasks, as well as the possible solutions. It is essential to identify these models prior to commencing the data collection process. In the current study, the students who were interviewed were asked to talk about the steps they were following to solve the problem. According to Leighton (2017), specific information about the participants with respect to level of knowledge and ability needs to be taken into account when selecting the task to be completed. In addition, when giving these instructions to the participants, the researcher must ensure they do not take the task as an evaluation, especially if such tasks are thought to be ability tests or achievement tests. Therefore, it is essential to minimise possible sources of stress and anxiety, by reiterating to the participants that the task at hand is not a measurement test and that the interviewer is not an expert either. This is why, in this study, I was particularly concerned about building a friendly relationship with the participants to minimise their stress during the task; they were also informed that their attempt to solve the problem had no effect on their grades in physics. Finally, it is essential to clarify the objectives of the study and the task and take all precautions in terms of sampling and participant selection based on these objectives.

Hence, in the current study, the interviewees were informed about the objectives of this study before starting the think aloud and they were also asked if they had any concerns about this protocol. It is important to note, however, that this study did not try to generalise findings because, in qualitative research, “the intent is not to generalize to a population, but to develop an in-depth exploration of a central phenomenon” (Creswell, 2012, p.206).

4.6.4 Classroom observations

Observations were carried out in this research to gain a greater understanding of the teaching methods used in the context of physics education in the KSA at the university level. It was important to conduct observations to get insights into the dynamics of the physics classrooms and the teaching methods used, including how teachers and students dealt with problem-solving in mechanics. Likewise, the proposed study used observations because it was crucial to attend physics classes in person to be able to collect meaningful and rich data. Observations allow researchers to discover what can be “unconsciously missed” or what participants “might not freely talk about” in the course of an interview (Cohen et al., 2011, p.456). Furthermore, observations provide researchers with live data on important domains, such as pedagogy or curriculum, and allow them to gain an in-depth understanding of the research context.

Observations can be classified into two categories: (1) participant observations and (2) non-participant observations (Cohen et al., 2011, Fraenkel, Wallen, & Hyun, 2012). For the purpose of this study, semi-structured participant observations were used to allow the researcher to become a member of the class and interact with students during lectures. For example, certain physics teachers gave me the chance to talk and discuss with students and get involved in group work activities or during an experiment using a pendulum.

The observation schedule was designed in light of the purpose of the current study (see Appendix 9) and consisted of 14 sections. The first section collected general information such as the teacher code, the level of the lecture, the date, the topic of the class and the classroom itself; the second section related to the steps of problem-solving; and the third part to the steps that teachers focused on. The fourth section was about the nature of the activity/content, while the fifth section was for the materials/teaching aids used during the physics lectures. The sixth section in the observation schedule covered the nature of the questions posed by teachers during the physics lectures; the seventh was about explaining the activity and how it related to the previous lessons; while the eighth focussed on how students' prior knowledge was discussed and the ninth concerned the teaching methods. The tenth section looked at whether students were being helped to reason through a thinking process or were being fed information; the eleventh examined whether students were looking for the correct answer or following the steps of problem-solving; the twelfth concerned the teachers' language in the physics lectures; the thirteenth focussed on the interaction between teachers and students or between students themselves, while the final section was for other comments during the classroom observations.

To assure the validity of the classroom observation form, it was sent to several experts in the field of science education, including my supervisor and colleagues in the School of Education at Exeter University, and one expert in science education from Taif University. They all agreed that the form was suitable for the goal of the study.

4.7 Practical procedure of data collection

The data was collected through seven stages, as follows:

4.7.1 Obtaining permission

Prior to commencing the process of data collection, I had to obtain a certificate of ethical approval from the Graduate School of Education at Exeter University (see Appendix 1). In addition, in order to adhere to the Saudi MoE and University of Taif ethical guidelines, I obtained permission to commence fieldwork from the University of Taif's administration (see Appendix 4). More specifically, the Deanship of the Science College, the Department of Physics and the Deanship of the Preparatory-year granted their approval to conduct this research in the form of a written permission. Also, students and teachers were given information sheets and consent forms (see Appendix 2 and 3).

4.7.2 Pilot study

A pilot study can be referred to as "a small-scale version of the real thing, a try-out of what you propose so its feasibility can be checked" (Robson, 2002, p.185), which enables researchers to discover certain problems by reconsidering the suitability of their procedures in advance (Cohen et al., 2011). In this study, the purpose of the pilot study was to develop and verify the methods used in this study; it gave me the opportunity to train myself to conduct the interviews, think aloud protocols and classroom observations prior to conducting the main study. Consequently, in this study, before commencing the field work, my research supervisors, an expert from Exeter University with a PhD in education and two postgraduate researchers from Exeter University revised the interviews, the think aloud protocols and observation schedules. Based on their recommendations, several modifications and amendments were made in relation to the clarity of some questions, to avoid overlapping questions and correct grammatical mistakes.

In addition, prior to commencing the main data collection, two questionnaires were administered to 50 students and three classroom observations were conducted. Moreover, face-to-face interviews were carried out with three teachers and four students for one week from February 2nd to 25th during the academic year 2015-2016, as shown in Table 4.6. For the think aloud protocol, students were given a mechanics problem they had to solve by thinking aloud about the steps they followed for the solution (see Appendix 10).

Table 4.6: Pilot study

Tools	Sunday	Monday	Tuesday	Wednesday	Thursday	Total
Teacher interviews	2	-	1	-	-	3
Student interviews	-	-	2	-	2	4
Think aloud with students	-	-	2		1	3
Observations	1	1	-	-	1	3
FCI, MBT questionnaire	-	27 students	-	23 students	-	50

The two questionnaires were distributed among 50 students who were selected purposefully. The participants were composed of 27 preparatory-year students and 23 first-year students, which corresponds to the two classes with the lowest number of students in each year; these two classes were not included in the main study. Four additional students (two preparatory-year and two first-year) and three teachers (one first-year and two preparatory-year) volunteered to take part in face-to-face interviews that lasted about 30 minutes. Pilot classroom observations were also carried out three times, once with a first-year class and twice in the preparatory-year. These classrooms to be observed were selected randomly, in order to familiarise myself with this method, to identify the best possible location in the classroom and to take into account what to concentrate on and record and where to look (Cohen et al., 2011).

As a result, the pilot study was a fundamental stage of the data collection process and provided determining information in order to refine the instruments and adequately plan for the main data collection study. In all, the pilot study was essential with respect to several points. Firstly, it allowed me to identify the best possible way to distribute and administer the two questionnaires, that is, the FCI in one lecture and the MBT during another lecture. As in the pilot study students seemed bored and wanted to complete these questionnaires quickly, I preferred to distribute the two questionnaires in two lectures rather than in one lecture. Secondly, I managed to find out how much time was needed to complete the questionnaire; for instance, I observed that students spent an average of 30 minutes to complete the FCI and MBT tests. Thirdly, the pilot study allowed me to identify the best possible locations within the university to conduct the interviews. Fourthly, it also allowed me to estimate and manage the length of the interviews and the think aloud protocol; interviews took around 50 minutes while the think aloud protocol took about ten minutes. Furthermore, while conducting the interviews and think aloud protocol, I asked participants about the clarity of the questions and, based on their responses, certain changes were made to the wording and order of the interview questions, and therefore, the final version of the interview and think aloud protocol were ready to be used for the main data collection. Finally, reliability tests were conducted during the pilot study for the two questionnaires, as follows:

4.7.2.1 Reliability and validity of the FCI questionnaire

The reliability of the Force Concept Inventory (FCI) has been reported by previous research (Hestenes & Halloun, 1995; Sahin, 2009), for the FCI questionnaire it was found to be 0.71. Hestenes et al. (1992), found a great confidence in the reliability of the FCI questionnaire. In the current study, Cronbach's alpha was used to measure the internal consistency coefficients of the FCI items. This was done during the pilot study with 43 students (21 first-year students and 22 preparatory-year students) because out of 50 students, seven students from both levels were excluded from the FCI and the MBT tests due to incomplete questionnaires or absence when the test was administered. Consequently, in total seven students were excluded. Considering that a value of Cronbach's alpha above 0.7 (70%) can be considered reliable and acceptable (Pallant, 2005) and that the result of the reliability statistics of the FCI (as shown in Table 4.7) was 0.871, the instrument can be considered reliable. In addition, the questionnaire had been already translated into Arabic and approved by the Excellence Centre of Science and Mathematics Education at King Saud University in Saudi Arabia, which is available at the Modeling Instruction Program at Arizona State University. Therefore, the FCI questionnaire could be used for the main data collection. The reliability of the categories of FCI are presented in Table 4.7.

Table 4.7: Reliability Statistics of two tests

Test	Cronbach’s Alpha	N of Items
FCI	.871	30
MBT	.867	26

Table 4.8: Reliability Statistics of the categories of FCI

Dimension	Cronbach's Alpha	N of Items
Kinematics	.247	6
First law	.557	8
Second law	.358	4
Third law	.303	4
Superposition principle	.442	4
Kind of forces	.844	12

4.7.2.2 Reliability and validity of the MBT questionnaire

With respect to the Mechanics Baseline Test (MBT), previous research had reported (Ates & Cataloglu, 2007) that the reliability estimate of the MBT questionnaire was 0.70. In the pilot study for this research, Cronbach’s alpha was also used to measure the internal consistency coefficients of the items of the MBT questionnaire with the same 43 students. The result (alpha = 0.867) is shown in Table 4.7, and is an acceptably high score and, therefore, suggests reliability of this construct. To increase the content validity of the MBT questionnaire, several steps were taken.

Firstly, the test was translated into Arabic by a native English speaker fluent in Arabic and studying Arabic at the Institute of Arab and Islamic Studies at Exeter University. Secondly, the translated version of the test was reviewed by two experts from King Saud University and King Abdul-Aziz University Physics College and revised by an expert from the University of Dammam Science College in Saudi Arabia. This ensured the items of the questionnaire included accurate physics notions and that the statements were unambiguous. Following recommendations, corrections were made to the Arabic versions and finally checked by another Arabic speaker from Taibah University in Saudi Arabia. The reliability of the categories of MBT are presented in Table 4.9. Therefore, the MBT questionnaire could be used for the main data collection.

Table 4.9 Reliability statistics of the categories of MBT

Category	Cronbach's Alpha	N of Items
Kinematics	.743	12
General principles	.829	19
Specific forces	.299	3

4.7.3 Preparing for data collection

At this stage, I met with the Dean of the Science College, the Dean of the Preparatory-year and the Head of the Department of Physics in addition to several teachers in the department in order to explain the aims and procedures of this research project. Also, we agreed about the timescale of this study in order to distribute the questionnaires among students.

4.7.4 Administration of the questionnaire

I met the teachers who kindly made arrangements to facilitate my access to the classes. In the first-year and preparatory-year classes, students attended a brief presentation about this research project and its aims and received instructions on how to adequately complete the questionnaires. For example, students were reminded not to write anything on these questionnaires, to choose only one answer per question and not to skip any questions. Moreover, they were reminded to avoid guessing. They were provided with a suitable pencil to shade in their answers on the answer sheets (see Appendix 11), and they were asked to write down their names and classes. Following this, the FCI paper questionnaires were distributed to both levels over the course of a week and, the following week, the MBT was distributed. It is worth bearing in mind that according to the FCI instructions and based on the pilot study, both the FCI and the MBT should be completed in about 30 minutes. Teachers helped to administer the questionnaires, encouraged all students to take part, and helped me to check whether students were sharing answers with others. I instructed students how to complete the questionnaires.

4.7.5 Conducting the interviews

37 face-to-face interviews were conducted in Arabic (the first language of the participants and the researcher) with teachers and students over a period of two months. In all, 24 interviews were conducted with Saudi preparatory-year and

first-year physics students (ten preparatory-year and eleven first-year students; three students were interviewed twice). 13 interviews were also conducted with physics teachers, including five preparatory-year teachers and five first-year (three teachers were interviewed twice). The reason why a small number of interviews were conducted twice was because of the teachers' and students' lack of time due their busy schedules. All interviews with students were conducted in a quiet room within the university, whereas teachers' interviews were conducted in their own offices.

The interviews were conducted over the course of seven weeks, as shown in Table 4.10. Interviews were conducted to gain a deeper understanding of students' and teachers' perceptions of students' problem-solving in physics. Also, during classroom observations, a number of issues were found to be related to the research focus and, therefore, needed to be discussed and understood in more depth through the interviews. Overall, all interviews lasted between 30 and 40 minutes.

Table 4.10: Number and spacing of interviews

Week	**Students**		**Teachers**		
	First-year	Preparatory-year	First-year	Preparatory-year	Total
6			Mid-term holiday		-
7	1	1	1	-	3
8	2	1	1	1	5
9	2	1	1	2	6
10	2	2	-	2	6
11	2	2	2	1	7
12	2	2	-	1	5
13	2	2	1	-	5
Total	13	11	6	7	37

All interviews were digitally recorded and transcribed immediately after each interview. A number of transcripts were sent to the corresponding participants for review and member checking, in order to confirm the accuracy of the transcripts.

In addition, it is important to mention that all the transcripts were in Arabic and that the analysis was done in Arabic because this is the language of both the participants and the researcher, so it was important not to lose the meaning of the participants' speech by translating from Arabic into English.

4.7.6 Conducting the think aloud protocol

At this stage, 21 students from both years participated in the think aloud protocol as follows: first, all students were provided with a piece of paper and a pen. Second, they were informed that their thinking aloud would be recorded, and they all gave their permission for this. Then they were given the following physics problem:

> *A box weighs 562 Newton on a tilted surface at a 30° angle. The force of gravity has two components, one perpendicular and one parallel to the incline. Find the two components of the weight force.*

Fourth, they were informed of the procedures they should follow during this stage. For example, they were asked to read the task, think out loud while solving the problem and speak about what they were thinking, but that they were not to feel under pressure. Also, they were informed that what they were doing would not affect their results in physics at all. Fifth, they were informed that I could not help them to solve the problem; rather that I was there to record their thinking aloud.

4.7.7 Conducting the classroom observations

In all, 11 semi-structured observations were conducted; four preparatory-year physics classes were observed in addition to two first-year physics classes. As a result, the total number of observations of first-year physics classes was five whereas six preparatory-year classes were observed (some classes were observed two or three times), as shown in Table 4.11. The reason behind that was the nature of the timetable of lectures and examinations at Taif University. Therefore, two cases (a teacher and his students) were observed focusing on problem-solving skills, one case with preparatory-year and the other with first-year. Through the observations, I sought to comprehend the dynamics of the classes in terms of problem-solving skills in the teaching and learning of physics.

The observations were carried out over a period of seven weeks and lasted for roughly 80 minutes. Each lecture was scheduled for 100 minutes, but some of the teachers did not attend on time or gave their students another ten minutes to ensure their attendance, and a further ten minutes to call the register and prepare the lecture. I began the observations using only written notes with two first-year physics classes and four preparatory-year physics classes, and I noted different aspects, such as what the teacher focused on in relation to the steps of problem-solving, the teaching methods, the teacher’s language, the interaction, the materials/teaching aids, the nature of the activity/content, whether teachers were helping students reasoning through thinking processes or by feeding information and discussing students’ prior knowledge. This is because these aspects play an important role in affecting students' ability to solve and understand physics problems.

Table 4.11: The number of observations for first- and preparatory-year classes

Class	First-year	Physics topic	Preparatory-year	Physics topic
1	2	Conservative and non-conservative forces	2	Velocity and motion
2	3	Newton's laws of motion	1	Circular motion
3	-		2	Newton's laws of motion
4	-		1	Projectiles
Total	5		6	

4.8 Data analysis

This section discusses the analysis of the data which were collected from questionnaires, interviews, think aloud protocols and observations; it focuses on two aspects: (1) quantitative data analysis and (2) qualitative data analysis.

4.8.1 Quantitative data analysis

In the main study, quantitative data were collected to measure the students’ levels of problem-solving skills and their understanding of basic physics concepts in order to understand the students' readiness to do problem-solving in physics. To do that, each test's scoring instructions were carefully read. According to the literature, an FCI score of 85% can be interpreted as the "Newtonian Mastery threshold" and students obtaining scores above this threshold can be confidently regarded as "confirmed Newtonian thinkers" while a score of 60% refers to what can be labelled as "the entry threshold to Newtonian physics". In other words, students who reach this threshold have merely started adequately dealing with Newtonian concepts in thinking (Hestenes & Halloun, 1995). Moreover, it seems that a score below the 60% threshold suggests that students' comprehension of Newtonian concepts is inadequate for successful problem-solving (Hestenes et al., 1992).

Scannable answer sheets were provided by Taif University (see Appendix 11) and students were asked to shade their answers using a pencil. Answer sheets were used in order to ease entering the numerical raw data to the Statistical Package for Social Science (SPSS, version 22). Following the completion of all questionnaires I coded the data into SPSS. For example, preparatory-year students were given the code (L0) whereas first-year students were given the code (L1). Also, the completed questionnaires (FCI, MBT) were given ID numbers. For example, first-year students' questionnaires were given numbers 1 to 82, which represents the total number of completed questionnaires, while preparatory-year students' questionnaires were given numbers 1 to 376, which also represents the total number of completed questionnaires. Moreover, all the items of the two questionnaires were scored into SPSS based on the responses of the students. If a student answered the questions correctly, he was given a score "1" and if not, he was given a score of "0". In addition, the overall scores were calculated for each student and also the scores they obtained in each category of the questionnaire. Collected data were stored in a secure and safe place and on my password-protected personal computer that is equipped with up-to-date anti-virus software. Furthermore, the data were checked by myself and my supervisor to ensure that they had been entered correctly into SPSS and that there were no missing data.

Descriptive and inferential statistics were used to analyse the data from the two questionnaires in order to understand the students' readiness to do problem-solving in physics. The test of normality was used to decide whether to use parametric or non-parametric tests (non-parametric tests were used in this study). Likewise, Spearman's correlation coefficient was used to investigate the correlation between the variables (the FCI and MBT). All these statistical tests are reported in more detail in the quantitative data analysis chapter.

4.8.2 Qualitative data analysis

In this study, thematic analysis was adopted as an approach to analyse the interviews, classroom observations and think aloud protocols. As this study adopted a sociocultural theoretical framework, this approach should strengthen the analysis and enhance its interpretative nature and broaden the spectrum of the data (Alblaihed, 2016). This is confirmed by Braun and Clarke (2006) who argue that "thematic analysis has limited interpretative power beyond mere description if it is not used within an existing theoretical framework that anchors the analytic claims that are made" (p.97). Hence, thematic analysis was used within a theoretical framework - the sociocultural framework for this study, which helped to focus on the social and cultural aspects surrounding the students in relation to physics problem solving This, therefore, led the data analysis to concentrate on the key aspects of this study and provide answers to the research questions.

In this study, interviews were transcribed while the observation results based on the predefined schedule (see Appendix 9) were written as text and treated like the interview transcripts. Issues and aspects observed in the classrooms were included under the themes that emerged from the analysis of the interviews. As for the think aloud protocols, they were recorded, transcribed and analysed in the same way as the interviews.

The following quote is an extract of an interview with one of the preparatory-year students:

> I don't understand the physics concept, but I memorized it with no deep comprehension of that concept, because some teachers don't clarify the physics meaning enough for us to comprehend.

The following extract is an example of a first-year physics classroom observation:

> It was noted during this class that only four students participated in the discussion with the teacher out of a total of thirty-seven students. The rest were not following the teacher and were occupied with their mobile phones or sleeping while others chatted with their classmates about topics

irrelevant to physics.

Also, the following quote is an extract of a think aloud transcript of one of the first-year students:

> I'm…. mmm I'm trying to imagine the problem in order to define the coordinates. First of all, ahh, okay, this coordinate is X with sine of the angle 30, and another one is Y with cosine of the angle 30. *mmm…* then, this is the tilted surface, *mmm*…what I have to do now is to find the required point which is… *mmm…* Find the two components of the weight force, but..ahh, I do not understand this […]. I feel that the solution requires something based on something else and this is a difficulty that confuses my understanding.

With respect to thematic analysis, Guest, MacQueen and Namey (2012) stated:

> Thematic analysis moves beyond counting explicit words or phrases and focuses on identifying and describing both implicit and explicit ideas within the data, that is, themes. Codes are then typically developed to represent the identified themes and applied or linked to raw data as summary markers for later analysis. (p.9)

This study used inductive thematic analysis because this approach is a flexible one which does not have strict rules, but which helps the researcher to get a rich description of the data. In this respect, thematic analysis "provides a flexible and useful research tool, which can potentially provide a rich and detailed, yet complex, account of data" (Braun & Clarke, 2006, p.78). In addition, the inductive approach was used because this study is not based on pre-set hypotheses. Furthermore, in this study, themes, categories and subcategories emerged *a posteriori,* and were not predetermined in advance, Indeed, in this interpretive research, I needed the ideas and themes to emerge from the data as a result of my interpretations to see what actually emerged from the students' and teachers' interviews, the classroom observations and think aloud protocols in order to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives.

In the current study, I adopted an inductive approach to thematic analysis that was inspired from the literature (e.g. Braun & Clarke, 2006; Frith & Gleeson, 2004; Nielsen, 2015; Raufelder et al., 2016). First, the interview recordings were carefully listened to several times to avoid errors or misinterpretations. They were then transcribed, and the transcripts read several times so that I immersed myself in the data while exploring it. The same procedure took place with the classroom observation and think aloud protocol data. Next, I started to read the first interview line by line considering the underlying meaning of each piece of the participant's answers, and I kept the research questions in mind throughout the analysis. Therefore, initial ideas that emerged from the data were noted and the data coded accordingly. The same process was repeated for all classroom observations and think aloud protocols. Coding can be defined as "the process of segmenting and labelling text to form descriptions and broad themes in the data" (Creswell, 2012, p.243). It is worth bearing in mind that during think aloud protocols and interviews with students regarding the problem-solving strategies (understanding the problem, devising a plan, carrying out the plan and looking back) used by students, these four steps came from the literature (Polya, 1957). According to Leighton (2017), it is essential to identify and adopt a cognitive framework established from research to be used with the targeted participants. Then, based on this framework, the researcher should be able to determine possible problems and challenges faced by participants in completing the chosen tasks, as well as the possible solutions. It is essential to identify these models prior to commencing the data collection process. In the current study, the students who were interviewed were asked to talk about the steps they were following to solve the problem during think aloud protocols. Also, during the interviews with students from both years, students were asked about these four steps and they expressed their views about them.

Moreover, as shown in Figure 4.3 below, I used MAXQDA, a qualitative data analysis software, to facilitate the process of analysis. I imported all data files into the software and organised them into eight documents. Each one had a list of files and each file was given a different code. For example, one preparatory-year teacher interview was given the code T9P, a first-year student interview was given the code S21F, a first-year student think aloud was given the code TAPS3, and a preparatory-year observation was given the code O10. Also, this software helped me to organise and store the data and therefore retrieve them easily. Moreover, it allowed me to generate codes and link them with the data.

In addition, this software was used because it is one of the only qualitative data analysis software packages that supports text in Arabic language. In this respect, it is worth bearing in mind the importance of analysis in the language of the participants. For instance, the analysis of idioms or metaphors in a qualitative study can reveal meanings based on subjective experiences (Van Nes, Abma, Jonsson, & Deeg, 2010). Furthermore, it was decided to conduct the analysis in the original language as much as possible to reduce the potential shortcomings in the analysis, which would also enhance the trustworthiness of the qualitative analysis (Vallance, Madang, & Lee,2005; van Nes et al., 2010). Thus, I did not want to reduce the meaning of the analysis by using a language other than Arabic. According to Vallance et al. (2005), there are certain advantages in conducting the analysis in the original language. Indeed, the analysis is more accurate, which means that the meaning of the participants' speech can remain as close to the original as possible. In addition, analysing the data in the original language gives the researcher an overview of the participants' ideas through reading the participant's conversation within the whole interview and thus builds a holistic analysis rather than a translation of the interviews. This is because translating into English might have caused the loss of what was embedded in the participants' speech. Finally, analysing in Arabic provided a nuanced interpretation of the data as the voice of the participants and their expression could be kept if the analysis was done in the original language to maximise insights into the nuances of speech across the whole interview (van Nes et al., 2010). When I translated themes, categories and codes into English, I made sure to retain the meaning by discussing the translation with a professional translator.

As a result, each interview, classroom observation and think aloud was read through the software interface and each emerging idea from the text was highlighted and attributed a new code, as shown in Figure 4.3 below. The same process was repeated for all interviews, classroom observations and think aloud protocols. Where similar ideas emerged, they were included in the same code.

The third step in the analytical process involved coding segments of data on the software by labelling and naming selected interview, classroom observation and think aloud extracts; therefore, various codes were generated from the data as shown in the screen shot below. The following table contains examples of codes applied to segments of data from interviews with a teacher and a student.

Table 4.12: Codes and segments of data

Segments of data	**Coded for**
"A lack of basic physics knowledge from school influences the level of students' thinking when they want to understand solving problems in physics." (T6F)	Lack of basic physics knowledge
"Students in physics class don't care about the lecture, they are browsing their mobile phones. This is due to students do not find anything that encouraging them to interact with their teachers; therefore, they won't think about anything else." (S13P)	Lack of interaction
What is this? This is the first time I see a problem like this, mmm…I do not understand the mechanics problem" (TAPS16)	Understanding the problem
"we directly start solving without any planning for the solving method" (S7F).	Devising a plan

Then I wrote the name of each code on a paper card to organise and sort them into potential themes. According Braun and Clarke (2006, p.89), potential themes are found by "sorting the different codes into potential themes and collating all the relevant coded data extracts within the identified themes".

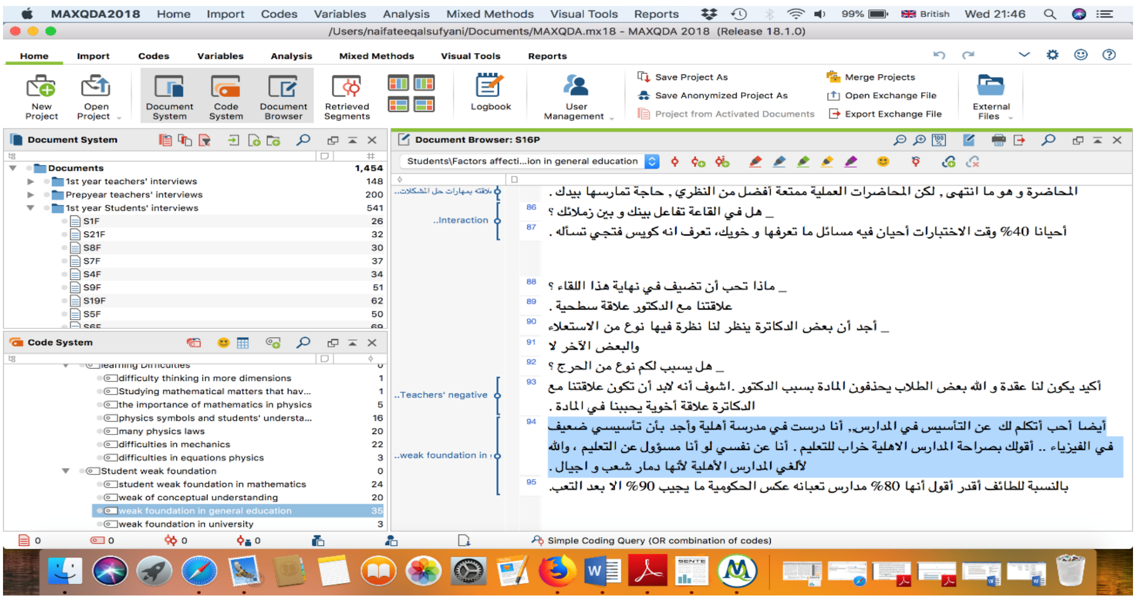

Figure 4.3: Qualitative data analysis software screen shot[1]

[1] Translation of the highlighted text in the screenshot: *"I studied in a private school and I found that I have a weak foundation in physics, and I can honestly say that private schools are considered to be destructive for general education, if I were responsible for general education, I would eliminate private schools because they are destructive to people and generations*".

Fourth, some initial ideas formed categories that composed the main themes (see Appendix 12). Fifth, when I generated a set of themes, they were reviewed and refined in relation to the coded extracts. To do this, all the collected extracts (interviews, observations and think aloud protocols) were read in order to ensure they composed a coherent pattern for each theme. Also, I reread the entire set of transcripts to ensure that the themes worked in relation to the data set and to code any further data which might have been missed in the beginning of the analysis. Then, a thematic map of the analysis was produced. Finally, all themes were reproduced on a thematic map (see Figure 4.4) refined and given names so that each theme made sense in a way that could tell a clear story in relation to the research questions. As a result of the analysis of the qualitative data, six themes emerged in relation to the research questions, as shown in Figure 4.4 below.

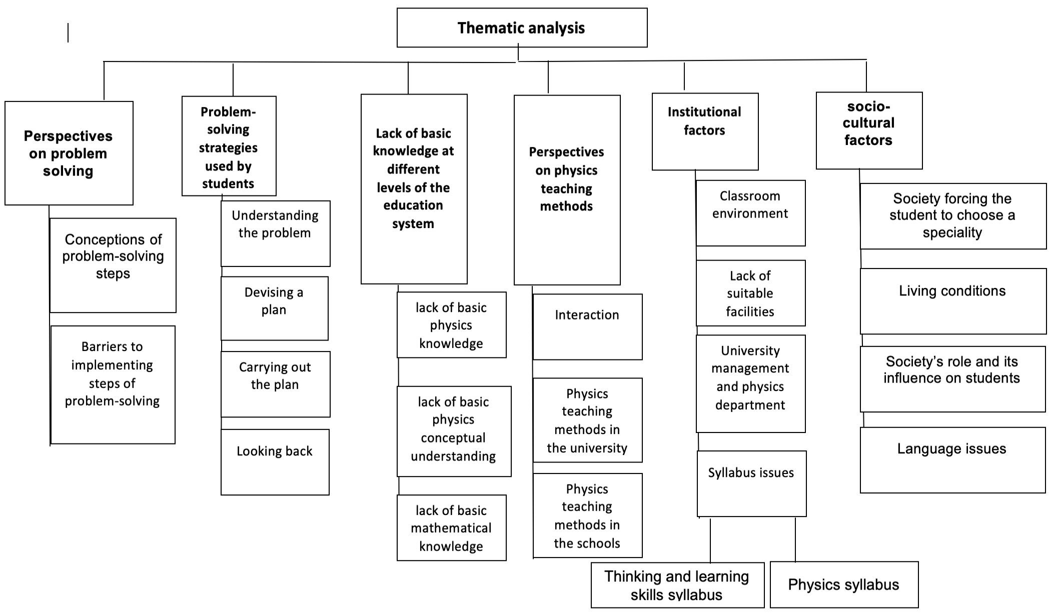

Figure 4.4: Thematic map of all data from interviews, classroom observations and think aloud protocols

The above figure highlights the sub-categories and categories with their related themes. The two categories “conceptions of problem-solving steps” and “barriers to implementing steps of problem-solving” belong to theme “perspectives on problem-solving”. Furthermore, “understanding the problem, devising a plan, carrying out the plan, looking back” fall under the theme: “problem-solving strategies used by students”. The three categories “lack of basic physics knowledge”, “lack of basic physics conceptual understanding” and “lack of basic mathematical knowledge” belong to the theme “lack of basic knowledge at different levels of the education system”. In addition, the three categories “interaction”, “physics teaching methods in the university” and “physics teaching methods in schools” constitute the theme: “perspectives on physics teaching methods”. Also, it can be seen that the four categories “classroom environment”, “lack of suitable facilities”, “university management and physics department” and “syllabus issues” relate to the theme “institutional factors affecting students’ learning of problem-solving in physics”. The two sub-categories “physics syllabus” and “thinking and learning skills syllabus” fall under the “syllabus issues” category.

Moreover, the four categories “society forcing the student to choose a speciality”, “living conditions”, “society’s role and its influence on the students” and “language issues” fall under the theme: “sociocultural factors affecting students’ learning of problem-solving in physics”.

4.9 Trustworthiness

Quality is an important element to take into consideration when conducting educational research. Trustworthiness in qualitative research can be defined as “a set of criteria advocated by some writers for assessing the quality of qualitative research” (Bryman, 2016, p.697). According to Lincoln and Guba (1985), the important point of the trustworthiness is: “How can an inquirer persuade his or her audiences that the research findings of an inquiry are worth paying attention to?” (p.290).

In this respect, two essential notions are thoroughly discussed in educational research in general and in scientific research in particular: validity and reliability. However, qualitative researchers do not refer to quality in these terms and use other concepts to address quality issues: credibility and dependability. Credibility in qualitative research parallels internal validity (Shenton, 2004), whereas the principle of dependability shows that the results are consistent and can be repeated in other settings (Lincoln & Guba, 1985; Thomas, Nelson & Silverman, 2005). In this study, to ensure the trustworthiness, a variety of strategies were used.

The proposed study ensured credibility in three different ways. First, four different instruments for collecting data (questionnaires, interviews, classroom observations, think aloud protocols) were used thus yielding a more in-depth understanding of the research problem, and from different perspectives and points of views. Second, member checking was used, so that my interpretations of teachers' and students' views were checked in order to ensure that such interpretations were accurate and appropriate in relation to the participants' perspectives about students' problem-solving in physics. For example, some teachers and students were interviewed more than once, and I also sent back interview transcripts to them in addition to think aloud transcripts to students. As a result of this, I found that my transcriptions of participants' responses were accurate. Third, the observation period was extended for up to a term and also, a pilot study was conducted in order to guarantee that the observational categories were suitable, exhaustive and unambiguous and effectively operationalised for the purposes of the research (Cohen et al., 2011). Also, the pilot study gave me a good opportunity to prepare and train myself to do the think aloud protocol before starting the main study.

With regard to dependability, for Yin (2009), qualitative researchers ought to accurately and precisely describe all the procedures of their research in a transparent manner in order to ensure that all the details are clearly presented to the research audience. In the current study, the procedures of data collection have been explained in detail in this chapter.

4.10 Ethical considerations

Issues of research ethics are considered to be an essential part of any work of educational research. Hence, dealing with these issues appropriately should be a top priority during the course of the research (Cohen et al., 2011; Wellington, 2000). In general, ethical issues revolve around the appropriateness of all procedures and steps conducted during the course of the research, particularly regarding formulating research questions and collecting and analysing data (Creswell, 2014). To assist researchers with conducting their research in an ethical manner, various organisations, such as the British Educational Research Association (BERA, 2018), offer different forms of help and guidelines. Fraenkel et al. (2012) highlight three key rules of research ethics: protection of the participants from any harm, confidentiality of research data and truthfulness of the research subject.

To confirm this study's compliance with a generally accepted set of ethical procedures, the University of Exeter and BERA (2018) ethical guidelines for research were strictly adhered to (see Appendix1). The first step conducted in this regard was to send a request to the University of Taif's administration to obtain permission to commence fieldwork. More specifically, the Deanship of the Science College (Department of Physics) and the Deanship of the Preparatory-year of the University of Taif gave their agreement to conduct this study. As a result, written permission was obtained to start data collection. Taif University approved the conduct of this research and assisted me with acquiring necessary permissions to conduct the study within the preparatory-year and the first-year (see Appendix 4). Secondly, for the qualitative methods, before starting the interviews, all participants were informed about the aims of the research and the protocol of the interview; their consent was formally sought using a form (see Appendix 3) and a participant information sheet (see Appendix 2) was given to them. BERA (2018) recommends the following:

> Researchers should do everything they can to ensure that all potential participants understand, as well as they can, what is involved in a study. They should be told why their participation is necessary, what they will be asked to do, what will happen to the information they provide, how that information will be used and how and to whom it will be reported. They also should be informed about the retention, sharing and any possible secondary uses of the research data. (p.9)

In addition, considerable effort was exerted to maintain absolute anonymity and confidentiality during all stages of the research. This included abstaining from using the real names of the participants as well as storing the collected data in a safe place. According to Radnor (2002), besides these specific measures, it is crucial that the researcher behaves with an utmost respect towards the participants. The participants were also informed that they could, at any point during the research, withdraw their participation without the need to provide any reason for doing so. (BERA, 2018)

Another ethical implication is that "vulnerability in an interview also comes from internal pressures. It is a situation in which it is very possible to lose face" (Powney & Watts, 1987, p.45). In this research, I tried to reduce that by seeking permission from participants prior to recording the interviews and, for every interview, participants were asked to choose a suitable time and place in order to help them talk freely. In addition, before all interviews I confirmed to them that their data would be dealt with in the strictest confidence and for the purpose of this research only. Furthermore, when the quantitative and qualitative methods were implemented, I was careful to build a friendly relationship with the participants to minimize the any stress they might experience.

It is worth mentioning that being a member of staff in the site being researched, this might have affected students' and teachers' responses. To minimise this effect, I informed participants that they had the right and ability to withdraw their participation from the research at any stage, and they were informed that their participation in the current study was not compulsory. Also, I informed the participants that their data would be kept in the strictest confidence to minimize any stress they might experience.

4.11 Research challenges

Certain issues were taken into account when conducting this study. Firstly, regarding the permission, initial approval was sought from Taif University and from the Saudi Arabian Cultural Bureau in London in order to be officially granted permission to conduct the study. Unfortunately, they refused my request and instructed me to contact Taif University again to obtain further permission with more details (who will be a supervisor on my research etc.), which I duly did.

Secondly, the distance between my home and the university was 37 miles and this meant I had to wake up early; and also due to the timetabling of lectures, which could be in the morning, midday or evening. To ensure my attendance at the lectures and facilitate the conduct of my research, I had to rent a flat which was much closer to the university, only two miles away.

Thirdly, with the quantitative data I collected around 1166 questionnaires (FCI and MBT) for both preparatory- and first-year students, and the volume of data was considerable. Fourthly, arrangements were sometimes thwarted as, for example, when I had an appointment with a teacher to visit his class and distribute the FCI questionnaires, but when I arrived the classroom was locked, and it took another 30 minutes to find another available classroom. Nevertheless, the teacher and students were very helpful in filling in the questionnaire that day, and the teacher shortened his lecture to 30 minutes (short lecture) in order to give me the rest of time.

Fifthly, when it came to the interviews, some participants were unwilling to take part because they were unfamiliar with interviews and they were only accustomed questionnaires. To address this issue, before conducting the interviews, participants were given the consent form and I explained the aims and procedures to them.

4.12 Summary of the chapter

This chapter explained the philosophical assumptions of the current study, followed by its research methodology and methods of data collection. Moreover, it discussed the data analysis procedures for both the quantitative and qualitative data. The trustworthiness of the data and ethical considerations were also discussed in this chapter. Finally, this chapter concluded by highlighting the challenges faced when conducting the study. In the next chapter, the quantitative findings resulting from the analysis of the data collected from the FCI and MBT questionnaires will be presented.

Chapter Five: Quantitative Findings

5.1 Introduction

In this chapter, the quantitative findings are presented based on the data collected from the two questionnaires: (1) the FCI, which measured students' understanding of basic concepts in mechanics, and (2) the MBT that assessed students' problem-solving skills in mechanics. All these tests were administered with preparatory-year students (L0) during a general physics lecture, while first-year students' (L1) questionnaires were completed during a mechanics lecture. They were administered and analysed over a period of four weeks at the beginning of the fieldwork. However, 37 preparatory-year students and 13 first-year students were excluded from the FCI and MBT questionnaires, so the total number of discarded questionnaires was 50, as mentioned in Chapter Four, in the sampling section.

The quantitative findings address the research question: "To what extent does the level of Taif University preparatory-year and first-year students' understanding of the basic concepts in mechanics allow them to solve physics problems adequately?" The aim was to understand the readiness of students from both years to solve physics problems.

This chapter provides a summary of the descriptive statistics for these two questionnaires. Furthermore, the distributions of the questionnaires (FCI and MBT) and their categories are highlighted, in addition to the correlation between the FCI and the MBT results. Finally, the chapter ends by presenting the MBT and FCI scores of the students selected for interviews.

5.2 Summary of the descriptive statistics for the two questionnaires

Some scholars (e.g. Ates, 2007; Gok, 2014; Hestenes, Wells, & Swackhamer, 1992; Sahin, 2009) have used mean and standard deviation with the FCI and MBT, when they analysed their data in relation to descriptive statistics. This is because the means give a measure the level of students' understanding of the basic concepts in physics and their problem-solving skills. The mean scores, mean percentage scores and standard deviations for each year group on each test are given in Table 5.1 and broken down by section in Table 5.2.

Table 5.1: Descriptive statistics for two questionnaires (FCI, MBT)

	Preparatory-year (n= 376)			First-year (n= 82)		
	Mean	Mean score %	Std. Deviation	Mean	Mean score %	Std. Deviation
FCI	6.05	20.17%	2.101	6.28	20.93%	1.834
MBT	4.64	17.84%	1.873	5.27	20.26%	1.798

As shown in Table 5.1, on the FCI test, the 376 preparatory-year students had a mean score of 6.05 out of a possible 30, or 20.2%, (SD = 2.101) and the 82 first-year students had a mean score of 6.28, or 20.9%, (SD = 1.834). It is clear that the mean scores and standard deviations for the preparatory-year and first-year on the FCI were close, with the first-year students scoring very slightly higher than preparatory-year students. Regarding the MBT test, the 376 preparatory-year students had a mean score of 4.64 out of a possible 26, or 17.84%, (SD = 1.873) and the 82 first-year students had a mean score of 5.27, or 20.3%, (SD = 1.798). The mean scores and standard deviations for the preparatory-year and first-year students on the MBT were also quite close, with the first-year scoring very slightly higher than preparatory-year students. These small differences will be tested for statistical significance later in this section.

According to the literature, an FCI score of 85% can be interpreted as the "Newtonian mastery threshold" and students obtaining scores above this threshold can be confidently regarded as "confirmed Newtonian thinkers" while a score of 60% refers to what can be labelled as "the entry threshold to Newtonian physics". In other words, students who reach this threshold have merely started dealing with Newtonian concepts adequately in their thinking (Hestenes & Halloun, 1995). Moreover, it seems that a score below the 60% threshold suggests that students' comprehension of Newtonian concepts is inadequate for successful problem-solving (Hestenes et al., 1992). As shown in Table 5.1, the mean percentage scores for preparatory-year and first-year students were well below 60% (respectively, 20.17% and 20.93%). Because of these low results on the FCI (below 60%), the ability of students to solve physics problems on the MBT test was below 60% too (17.84% and 20.26% respectively). This suggests that students could not solve physics problems because they did not have adequate Newtonian concepts for successful problem-solving.

Table 5.2: Summary descriptive statistics for the categories of the FCI and MBT for preparatory-year and first-year students

	Categories	**Preparatory-year students**			**First-year students**		
		Mean	Mean Score%	S.D.	Mean	Mean Score %	S.D.
FCI	Kinematics	1.15	19.16%	.958	1.19	19.83%	.948
	First law	1.56	19.51%	1.06	1.75	21.87%	1.095
	Second law	1.11	27.97%	.860	1.30	32.50%	.870
	Third law	0.65	16.40%	.698	0.56	14.00%	.686
	Superposition Principle	0.60	15.22%	.664	0.86	21.50%	.812
	Kind of forces	2.76	23.05%	1.361	2.98	24.83%	1.401
MBT	Kinematics	2.08	17.33%	1.288	2.40	20.00%	1.205
	General principles	3.29	17.31%	1.675	3.60	18.95%	1.661
	Specific forces	0.46	15.33%	.640	0.56	18.66%	.649

Table 5.2 shows that the mean percentage scores in all categories of the FCI questionnaire were well below 60% for both years. Also, the scores were nearly all slightly higher for first-year students than preparatory-year students. In more detail, the mean percentage scores for the preparatory- and first-year students respectively were: kinematics 19.16% and 19.83% (SD=.958, .948); first law 19.51% and 21.87% (SD=1.06, 1.095); kinds of forces 23.05% and 24.83% (SD=1.361, 1.401). In the second law, 27.97% and 32.50% (SD=.860, .870), and superposition principle, 15.22% and 21.50% (SD=.664, .812), the first-year students had a greater lead over the preparatory-year students. In contrast, preparatory-year students did a little better than first-year students on the third law 16.4% and 14.00% (SD=.698, .686).

Regarding the MBT test, first-year students' mean scores were slightly higher on all categories of the MBT questionnaire than the preparatory-year students': kinematics 17.33% and 20.00% (SD=1.288, 1.205); general principles 17.31% and 18.95% (SD=1.675, 1.661); and specific forces 15.33% and 18.66% (SD=.640, .649).

As shown in Table 5.2, the mean percentage scores on all categories of the MBT questionnaire were well below 60% for both years. It would be expected that there is a relationship between students' understanding of the basic concepts in mechanics, which was measured by the FCI, and students' problem-solving skills about basic concepts in mechanics, which was measured by the MBT. In other words, if students get below 60% on the FCI, they are very likely to get below 60% on the MBT.

In the next section I explore whether first-year students' level in the FCI and MBT was higher that than preparatory-year students' level. Hence, I compared the mean scores of two different levels (preparatory-year and first-year students) on two questionnaires and their categories. I would expect the first-year students to score higher than preparatory year students on the FCI and MBT test because the first-year students had been taught "Thinking and Learning Skills" and also physics in their preparatory year.

To decide whether the differences in percentage scores between the two year groups were statistically significant, statistical tests had to be carried out. To decide which kind of statistical test to use (parametric or non-parametric), a test for the normality of the distribution of the scores was performed. Because the sample size was 376 preparatory students and 82 first-year students, the Kolmogorov- Smirnov test of normality was used as, according to Innes (2009, cited in Alsenaidi, 2012), if n ›50, the Kolmogorov- Smirnov test is the correct one to use. To interpret the result of this test, if the "sig" value is below or equal to 0.05, it means that the scores are not normally distributed and that non-parametric tests need to be used; on the other hand, a "sig" value above 0.05 means that the distribution of scores is normal and therefore that parametric tests should be used.

5.3 Distributions for the FCI questionnaire across the two groups

Looking at the distributions of total scores on the FCI for the two groups, the Kolmogorov-Smirnov test gave a value of "sig" of .001 and .000 for each year group respectively, which is below 0.05, as shown in Table 5.3, which means that the results were not normally distributed.

Table 5.3: Tests of normality for the FCI questionnaire

Group	Kolmogorov- Smirnov			Shapiro-Wilk		
	Statistic	df	sig	Statistic	df	sig
L1	.134	82	.001	.965	82	.026
L 0	.116	376	.000	.971	376	.000

As a result, non-parametric tests were used. To test for the significance of the difference between the total scores on FCI for the two-year groups, the Mann-Whitney U test was performed because this is the non-parametric test to use where there is an independent variable of two categories (preparatory- and first-year) and a continuous independent variable (FCI score) as shown in Table 5.4.

Table 5.4: Hypothesis test summary for the FCI questionnaire

1	Null hypothesis	Test	Sig	Decision
	The distribution of total scores of the FCI is the same across categories of group.	Independent-samples Mann-Whitney U test	.239	Retain the null hypothesis.

From Table 5.4 above, it can be seen that the "sig" is .239, which means that the null hypothesis was accepted. In other words, the Mann-Whitney U test revealed that there was no statistically significant difference between the first-year students and the preparatory-year students with respect to the FCI questionnaire in total.

Regarding the FCI categories, on the Kolmogorov-Smirnov test the value of "sig" is .000 for both first-year and preparatory-year students, which is below

0.05 (see Table 5.5), which means that the results were not normally distributed. As a result, non-parametric tests were used, as shown in Table 5.6.

Table 5.5: Tests of normality for the FCI categories

Category/group		**Kolmogorov-Smirnov**			**Shapiro-Wilk**		
		Statistic	**df**	**Sig.**	**Statistic**	**df**	**Sig.**
Kinematics	L1	.240	82	.000	.867	82	.000
	L0	.220	376	.000	.869	376	.000
First law	L1	.206	82	.000	.907	82	.000
	L0	.209	376	.000	.903	376	.000
Second law	L1	.259	82	.000	.857	82	.000
	L0	.257	376	.000	.857	376	.000
Third law	L1	.342	82	.000	.732	82	.000
	L0	.289	376	.000	.771	376	.000
Superposition Principle	L1	.264	82	.000	.810	82	.000
	L0	.312	376	.000	.753	376	.000
Kind of forces	L1	.150	82	.000	.945	82	.000
	L0	.181	376	.000	.936	376	.000

Table 5.6: Hypothesis test summary for the FCI categories

Null hypothesis	Test	Sig	Decision
The distribution of kinematics is the same across categories of group.	Independent-samples Mann-Whitney U test	.713	Retain the null hypothesis.
The distribution of first law is the same across categories of group.	Independent-samples Mann-Whitney U test	.151	Retain the null hypothesis.
The distribution of second law is the same across categories of group.	Independent-samples Mann-Whitney U test	.078	Retain the null hypothesis.
The distribution of third law is the same across categories of group.	Independent-samples Mann-Whitney U test	.225	Retain the null hypothesis.
The distribution of superposition principle is the same across categories of group.	Independent-samples Mann-Whitney U test	.010	Reject the null hypothesis.
The distribution of kind of forces is the same across categories of group.	Independent-samples Mann-Whitney U test	.160	Retain the null hypothesis.

Table 5.6 above indicates that the "sig" of kinematics, first law, second law, third law and kind of forces are above 0.05, which means that the null hypothesis was accepted. In other words, the Mann-Whitney U test revealed that there was no statistically significant difference between the first-year and the preparatory-year students with regards to these categories of the FCI questionnaire. On the other hand, the "sig" of superposition principle is below 0.05, which means that the null hypothesis was rejected. In other words, the Mann-Whitney U test revealed a statistically significant difference between the first-year and the preparatory-year students with respect to this category of the FCI questionnaire

(superposition principle), with first-year students scoring higher than preparatory-year students.

5.4 Distribution of the MBT questionnaire across the two groups

For the total scores on the MBT questionnaire for each group, the Kolmogorov-Smirnov test gave values of "sig" of .003 and.000, which are below 0.05 (see Table 5.7), which means that the results were not normally distributed. As a result, non-parametric tests were used.

Table 5.7: Tests of normality for the MBT questionnaire

Group	Kolmogorov- Smirnov			Shapiro-Wilk		
	Statistic	**df**	**sig**	**Statistic**	**df**	**sig**
L1	.124	82	.003	.956	82	.026
L 0	.127	376	.000	.964	376	.000

To test for the significance of the difference between the total scores on MBT for the two-year groups, the Mann-Whitney U test was again, for the same reasons as for the FCI test. The result is shown in Table 5.8.

Table 5.8: Hypothesis test summary for the MBT questionnaire

1	Null hypothesis	Test	Sig	Decision
	The distribution of total scores of the MBT is the same across categories of group.	Independent-samples Mann-Whitney U test	.004	Reject the null hypothesis.

Table 5.8, above, shows that the "sig" is .004, which means that the null hypothesis was rejected. In other words, the Mann-Whitney U test revealed a statistically significant difference between the first-year and the preparatory-year students with respect to their total scores on the MBT questionnaire. The first-year students scored higher than preparatory-year students.

Regarding the MBT categories, looking at the normality of the distribution of the scores, the Kolmogorov-Smirnov test gave values of "sig" as .000 for both first-year and preparatory-year students. Because this is below 0.05 (see Table 5.9), it means that the results were not normally distributed. As a result, the Mann-Whitney U test was used to test for the significance of the differences between the means by year group, as shown in Table 5.9 and 5.10.

Table 5.9: Tests of normality for the MBT categories

Group		Kolmogorov- Smirnov			Shapiro-Wilk		
		Statistic	df	Sig.	Statistic	df	Sig.
Kinematics	L1	.216	82	.000	.924	82	.000
	L0	.195	376	.000	.930	376	.000
General principles	L1	.163	82	.000	.944	82	.001
	L0	.150	376	.000	.961	376	.000
Specific forces	L1	.330	82	.000	.737	82	.000
	L0	.374	376	.000	.696	376	.000

Table 5.10: Hypothesis test summary for the MBT categories

	Null hypothesis	Test	Sig	Decision
1	The distribution of kinematics is the same across categories of group.	Independent-samples Mann-Whitney U test	.034	Reject the null hypothesis.
2	The distribution of general principles is the same across categories of group.	Independent-samples Mann-Whitney U test	.134	Retain the null hypothesis.
3	The distribution of specific forces is the same across categories of group.	Independent-samples Mann-Whitney U test	.179	Retain the null hypothesis.

Table 5.10 shows that the “sig” of kinematics is below 0.05, which means that the null hypothesis was rejected. In other words, the Mann-Whitney U test revealed a statistically significant difference between the first-year and the preparatory-year students with respect to this category of the MBT

questionnaire (kinematics), with the first-year scoring higher. On the other hand, regarding general principles and specific forces, the "sig" levels were.134 and .179, which means that the null hypotheses were accepted. In other words, the Mann-Whitney U test revealed that there were no statistically significant differences between the first-year and preparatory-year students in their scores on these two categories of the MBT questionnaire.

5.5 Correlation between first-year students and preparatory-year students in relation to the FCI and the MBT

It was important to investigate the correlation between these variables (FCI, MBT) because it is to be expected that there is a relationship between conceptual understanding and problem-solving skills (Hestenes et al., 1992; Kim & Pak, 2002). Moreover, the MBT scores should be compared with the FCI results as students' comprehension of Newtonian concepts is essential for successful problem-solving (Hestenes et al., 1992). Therefore, it was important to measure the correlation between students' understanding of the basic concepts in mechanics on the FCI and their level of physics problem-solving skills as measured by the MBT.

According to Pallant (2005), the Pearson correlation coefficient is used in parametric statistics and Spearman's correlation coefficient in non-parametric statistics. As previously shown, in Table 5.3 and Table 5.7, the FCI and the MBT scores were not normally distributed so the non-parametric, Spearman's correlation coefficient, was used. In addition, to determine the strength of the correlation relationship, Cohen (1988) classified the values of correlation coefficients as follows:

r=.10 to .29 or r=-.10 to -.29 small
r=.30 to .49 or r=-.30 to -.49 medium
r=.50 to 1.0 or r= -.50 to -1.0 large.

In this section, I explore the correlation between students' understanding of the basic concepts in mechanics as per the FCI scores and their level of problem-solving skills as measured by the MBT.

Table 5.11: Correlation between FCI and MBT scores

Level	Spearman correlation coefficient	Sig level
First-year students	.398	.000
Preparatory-year students	.320	.000

Table 5.11 shows that, for each of the years, the value of the Spearman correlation coefficient between the FCI and MBT scores was between .3 and .4 and was statistically significant. This shows a medium-sized correlation between the two scores. Thus, there was relationship between students' understanding of Newtonian concepts as shown on the FCI test and their ability to solve mechanics problems as shown on the MBT. For first-year students, the scores on the FCI and MBT were significantly correlated (rho=.398, p=.000). For the preparatory-year students, also, the scores on the two tests were significantly correlated (rho=.320, p=.000).

5.6 Selection of students for interview

Table 5.12: FCI and MBT scores of students who were interviewed

Students selected for interviews	Level	FCI		MBT	
		Score	Percentage	Score	Percentage
1	First-year students	7	23.33%	6	23.07%
2		6	20.00%	7	26.92%
3		6	20.00%	5	19.23%
4		6	20.00%	5	19.23%
5		4	33.33%	2	7.69%
6		5	16.66%	5	19.23%
7		4	13.33%	3	11.53%
8		7	23.33%	9	34.61%
9		10	33.33%	8	30.76%
10		7	23.33%	7	26.92%
11		5	16.66%	5	19.23%
12	Preparatory-year students	8	26.66%	8	30.76%
13		5	16.66%	6	23.07%
14		6	20.00%	5	19.23%
15		7	23.33%	8	30.76%
16		5	16.66%	5	19.23%
17		4	13.33%	5	19.23%
18		10	33.33%	7	26.92%
19		12	40.00%	4	15.38%
20		7	23.33%	3	11.53%
21		10	33.33%	11	42.30%

Table 5.12 shows the mean percentage scores of the preparatory-year and first-year students who were selected for interview. It shows that their understanding of the basic concepts in mechanics (measured by the FCI) and their levels of problem-solving skills (measured by the MBT) were well below 60%. This table was used during the interviews to show students their scores on all tests and discuss why they obtained such low scores on the FCI and MBT.

Because the quantitative results, as shown in Table 5.1, did not provide enough information about students' problem-solving skills in physics and the reasons which might prevent them from solving physics problems effectively, I needed to engage with students of both years in in-depth discussions about their difficulties in problem-solving. Therefore, this study used qualitative follow-up procedures to gain a deeper understanding of students' problem-solving in physics by exploring university teachers' and students' perspectives. Therefore, as shown in Table 5.12, I selected students to be interviewed to gain a deeper understanding of the reasons behind their difficulties in problem-solving, their score below 60% and their apparent limited understanding of Newtonian concepts. At this stage, several questions were raised in terms of the pedagogy used in the teaching and learning of physics, the students' lack of knowledge and skills in physics and physics concepts, and the role played by the community in this problem.

5.7 Summary of the chapter

A number of issues emerged from the quantitative analysis. Principally, I found that the students' understanding of Newtonian concepts was below the 60% threshold on the FCI, meaning that their comprehension of Newtonian concepts was inadequate for successful problem-solving (Hestenes et al., 1992). Hence, the results of the MBT questionnaire also showed that all students scored below 60%, as shown in Table 5.1 and Table 5.2. Therefore, 21 students were asked during their interviews about the ideas underlying the Newtonian concepts and why they thought they were unable to understand these concepts.

Moreover, the correlation between students' understanding of the basic concepts in mechanics and their problem-solving skills in mechanics was found to be a medium-sized one and was statistically significant. These issues are discussed further in the qualitative study section through investigating the perceptions of university students and teachers about students' problem-solving in physics.

Chapter Six: Qualitative Findings

6.1 Introduction

This chapter presents the study results obtained through conducting interviews with both preparatory-year teachers and first-year teachers, and also with preparatory-year students and first-year students. Furthermore, it reveals the results of classroom observations of both years that have been used in this study as a supporting tool for clarity or for emphasis on issues that have been raised during the interviews. In addition, think aloud protocols were used with students solving a mechanics problem.

Before starting the presentation of the findings, it is worth briefly mentioning certain issues related to teaching and learning physics in the preparatory-year and first-year in Taif University. First, students in the preparatory-year are just taught one syllabus called General Physics, whereas students in the first-year are taught a variety of physics syllabuses (as detailed in Chapter Two). The teachers involved with these students (five preparatory-year teachers and five first-year teachers) come from different Arab countries such as Egypt, Algeria, Tunisia, Jordan, Palestine and Saudi Arabia. Class sizes range from 40 to 60 students, and preparatory-year students are taught one lecture per a week for an hour and 40 minutes, first-year students are taught one lecture per a week for an hour and 40 minutes and another lecture for fifty minutes.

In this chapter, the results of all the participants have been merged together instead of displaying them separately, for two reasons: firstly, the close similarity between the opinions of preparatory-year students and teachers and the opinions of first-year students and teachers; and secondly, to provide a comprehensive view of the perspectives of teachers and students regarding students' problem-solving in physics.

The current study took into consideration the sociocultural perspective, based on the notion that context is an important contributor to the interaction between people and, therefore, to the learning process. Sociocultural theory puts the focus on aspects of the context that may influence the solving of physics problems, by shedding light on relevant aspects of the Saudi social context.

A set of pseudonyms and codes were used in this study to identify participants who took part in the interviews. The following pseudonyms were used for preparatory-year students: S2P, S11P, S12P, S13P, S14P, S15P, S16P, S17P, S18P and S20P; these for first-year students: S1F, S3F, S4F, S5F, S6F, S7F, S8F, S9F, S10F, S19F and S21F; for preparatory-year teachers: T2P, T3P, T5P, T8P and T9P; and for first-year teachers: T1F, T4F, T6F, T7F and T10F.

Regarding classroom observations, the following codes were used for the preparatory-year class observations: O6P, O7P, O8P, O9P and O10P; and for first-year classroom observations: O1F, O2F, O3F, O4F and O5F. Moreover, for the think aloud protocols, preparatory-year students were assigned the following codes: TAPS2P, TAPS11P, TAPS12P, TAPS13P, TAPS14P, TAPS15P, TAPS16P, TAPS17P, TAPS18P and TAPS20P, whereas first-year students were coded as follows: TAPS1F, TAPS3F, TAPS4F, TAPS5F, TAPS6F, TAPS7F, TAPS8F, TAPS9F, TAPS10F, TAPS19F and TAPS21F.

In addition, after adopting an inductive approach to analysis, as mentioned in the Methodology Chapter, six main themes emerged through the analysis, as shown in the thematic map (see Figure 4.4) :(1) perspectives on problem-solving, (2) problem-solving strategies used by students, (3) lack of basic knowledge at different levels of the education system. All these three themes are related to RQ2). (4) Perspectives on physics teaching methods (related to RQ3), (5) institutional factors affecting students' learning of problem-solving in physics (related to RQ4), and (6) sociocultural factors affecting students' learning of problem-solving in physics (related to RQ5). These six main themes are presented in the following sections with their corresponding references from the participants' responses.

6.2 Perspectives on problem-solving

In the course of interviews, participants expressed their opinions about the steps of problem solving. Teachers and students from both years mainly referred to this aspect in two different ways: (1) they expressed their conceptions of problem-solving steps and (2) they referred to the barriers to implement these steps, as Figure 6.1 shows.

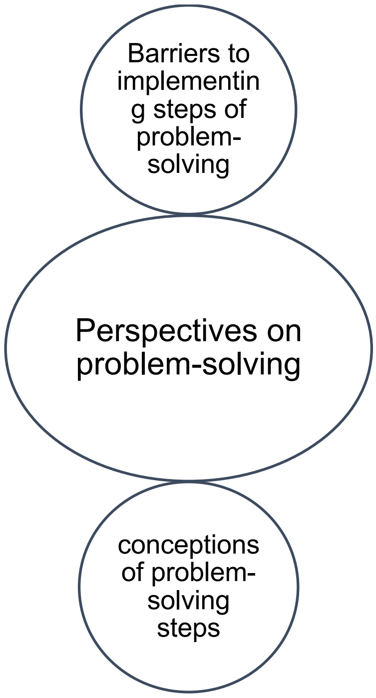

Figure 6.1: Perspectives on problem-solving

6.2.1 Conceptions of problem-solving steps

The participating students and teachers in both the preparatory- and first-year talked about the steps of problem-solving in physics from different angles; they referred to the steps of problem-solving differently. For example, they mentioned the practical aspect of problem-solving steps, such as searching for an alternative plan, understanding the physics problem and defining the problem. Other participants related the steps of problem-solving to mathematical formulae, understanding the barriers, using scientific thinking, or using physics laws. The participants' views on the steps of problem-solving are presented below.

When asking a preparatory-year student (S18P) what the steps of problem-solving in physics meant to him, he indicated: "thinking about the problem in order to solve it in a mathematical formula". Two preparatory-year students saw that the steps of problem-solving are related to finding physics laws: for example, a preparatory-year student (S12P) explained that the key to problem-solving is "finding the law to reach the solution of the problem". A preparatory-year student (S15P) described it as "searching for an alternative plan or alternative law", while a preparatory-year student (S20P) saw that the steps of problem-solving related to searching for alternative solutions "with any physics problem, we don't rush its solution but search for multiple solutions".

Moreover, a first-year student (S5F) considered that the steps of problem-solving are to know the challenges and he also believed that it is important to practice solving physics problems in order to overcome such challenges: “knowing the obstacles that you may face while dealing with a physics problem, thus the repetition of solving physics problems is beneficial in solving physics problems”. Also, a first-year student (S8F) believed that solving problems involves using particular steps but he did not mention these steps: “the solution involves specific steps”. In addition, a first-year student (S9F) claimed that the key to problem-solving is understanding the problem “defining the problem then solving it”. Another first-year student (S19F) explained that the means of problem-solving are to find different ways to solve the problem: “solving the physics problem in one way or another”.

From the teachers’ interviews, a preparatory-year teacher (T2P) believed that the key to problem-solving is understanding the problem in more detail: “the full conception of the physics-related meaning in a way that allows comprehension of the problem in more detail”. Also, a preparatory-year teacher (T5P) saw that the steps of problem-solving in physics relates to scientific procedures which a student should follow to find the solution: “how the student reaches the result on a systematic scientific basis in a way that makes the person convinced and confident with his steps”.

A preparatory-year teacher (T9P) explained his role with his students when dealing with physics problems, but he did not clearly mention the steps of problem-solving: “I direct the student if there is a specific problem. We describe the problem from a physics perspective, then we try to stimulate the students into thinking about the problem”.

A first-year teacher (T4F) saw that the steps of problem-solving are that students should employ physics laws and use them in an appropriate way, but he did not mention the steps of problem-solving:

> Problem solving steps, means that the student should employ physics laws which he has studied and try to explain them in a way suitable to physics.

A first-year teacher (T7F) agreed with T5P about the means of problem-solving, saying that it relates to using scientific ways of thought: “the use of proper scientific thinking and proper steps to reach the solution”. When asking a first-year teacher (T1F) during an interview about the steps of problem-solving, he mentioned the steps of problem-solving, but his focus was on the understanding and analysis of the problem:

> Multiple aspects are involved in problem-solving. The first step is understanding the problem because if the problem isn't understood, there is no point in searching for the solution [...]. Then, attempting to analyse the problem. It might be a combined problem, so I analyse it into separate partial problems, then I solve each problem separately. Afterwards, we gather the solutions with each other to get the problem's solution.

6.2.2 Barriers to implementing the steps of problem-solving

More than half the students (nine preparatory-year and six first-year), five preparatory-year teachers and two first-year teachers discussed their opinions during the interviews about implementing the steps of problem-solving when solving mechanics problems.

For instance, three preparatory-year students and one first-year student mentioned the aspect of time. This plays an important role in giving them the opportunity to implement the steps of problem-solving. For instance, a first-year student S3F held the view that the reason why he did not implement the steps of problem-solving was shortage of time:

> Sometimes, I apply the steps of problem-solving and this depends on the time I will use in searching for the data in the mechanics problem. So, the application of the steps of problem-solving takes time, because I am not accustomed to deal with these steps. I mean that I do not apply the steps but instead, I move directly to the application of the law which I have memorized to solve the problem quickly.

When asking a preparatory-year student (S11P) if he wished to add anything at the end of the interview, he emphasised increasing the lecture time in order to give students the opportunity to implement problem-solving steps:

> I wish an hour was added to the lecture of physics in the preparatory-year so there would be physics problems which contain more challenges for students' thinking and there would be time to carry out problem-solving steps in order to make the students more interested.

A preparatory-year student (S12P) also highlighted the aspect of increasing the number of physics lectures in order to get enough time to understand how problem-solving steps are implemented: "I suggest that the scientific subjects like physics should be of three hours instead of two hours in order to make time to understand how to apply problem-solving steps".

Meanwhile, one of the preparatory-year students (S18P) expressed how he felt when solving mechanics problems and acknowledged that he did not give himself adequate time to implement the necessary steps:

> I feel when dealing with the solution of the mechanics problems in physics that I'm trapped and restricted by a set time to solve the problem. This may be due to the fact that I am one of those people who like to act fast in their affairs.

Moreover, student participants from both years mentioned the reasons preventing them from implementing the steps of problem-solving in physics. These reasons are related to understanding the physics problem, understanding the physics syllabus, the difficulty of physics problems and the lack of awareness of the importance of the steps of problem solving. For example, a first-year student S5F explained that if the physics problem was difficult, he could not implement the steps of physics problems: "I may apply the steps of problem-solving if the mechanics problem is easy and direct, as I mentioned to you, otherwise I won't use them". In the same regard, a first-year student (S21F) considered that the implementation of the steps of problem-solving in physics depended on understanding the physics syllabus:

> Implementing the steps of problem-solving depends on understanding the syllabus. If I understand the syllabus, I can think, conclude and use the steps of problem-solving. But, if I only understand the syllabus partially, then the application of the steps will be difficult.

Meanwhile, one of the preparatory-year students (S2P) saw that the difficulty of physics problems was one of the reasons which prevented him from implementing the steps of problem-solving in physics: "Sometimes, I follow the steps of problem-solving because I find that physics problems are difficult for me and I need to think about them; also, I sometimes do not see the significance of using these steps in my learning". A preparatory year student (S15P) clearly stated that he did not care about the steps of problem solving: "everyone has his own way of solving and understanding, as for me, I don't see the importance of problem-solving steps". Also, a first-year student (S9F) believed that these steps are not needed in all mechanics problems: "I cannot see the importance of the steps of problem solving, and I don't need to use these steps because some mechanics problems don't require the application of these steps".

When asking the teachers about how students dealt with the steps of problem-solving, all the teachers agreed that the students did not follow any systematic steps while dealing with physics problems. For example, a preparatory-year teacher (T2P) mentioned that: “students’ approach to solving problems is totally random; they do not have any perception about applying the steps of problem-solving”. Also, a preparatory-year teacher (T5P) emphasised that students do not consider the steps of problem-solving in physics. This teacher was wondering why students jumped to the solution without following these steps: “The student does not give enough attention to the application of the steps of problem-solving, so he jumps directly to the conclusion without giving it enough time”. Although this teacher stated that the important issue for him was to find the result regardless of the steps of problem-solving because he believed that students know these steps: “I don’t use these steps and I don’t focus much on the method of problem-solving. I care about the final result and I’m in a hurry, as the students know these steps”. Moreover, a preparatory-year teacher (T8P) was critical about his students in relation to their use of the steps of solving physics problems: “The students’ approach to problem-solving steps is weak and they prefer to memorize previous formulas”. From another perspective, a first-year teacher (T4F) mentioned that students do not follow clear systematic steps during their thinking in solving physics problems: “the students’ problem is that they have no systematic approach to dealing with problem-solving”.

The above quotes from students of both years indicate that the students did not seem to implement the steps of problem-solving in physics except for three students (S10F, S13P, S20P). These three stated clearly that they used these steps in solving physics problems. Teachers emphasised that their students did not consider the steps of problem-solving in physics.

By reviewing participants’ perspectives about implementing the steps of problem-solving, it would be helpful to investigate how preparatory-year and first-year students deal with physics problems; therefore, in the next section, the findings relating to the second theme are presented: *problem-solving strategies used by students.*

6.3 Problem-solving strategies used by students

This section focuses on strategies used by preparatory-year and first-year students when dealing with physics problems, drawing on data from interviews, observations and think aloud protocols with respect to: (1) understanding the problem, (2) devising a plan (3) carrying out the plan, and (4) looking back, as Figure 6.2 shows.

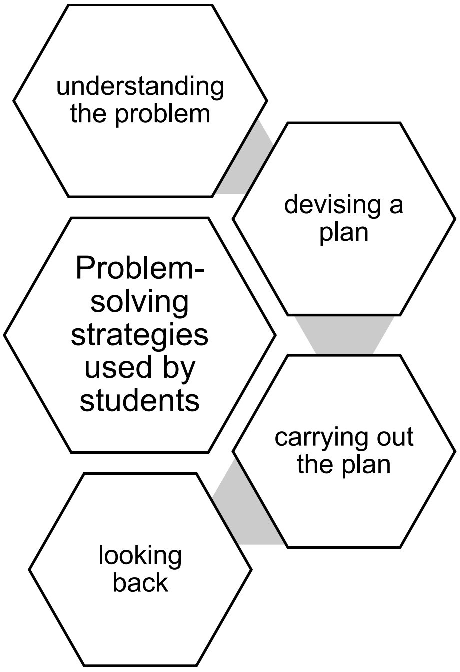

Figure 6.2: Problem-solving strategies used by students

6.3.1 Understanding the problem

The findings of the data analysis indicate that students from neither year seemed to use the steps of problem-solving during their thinking to help them understand physics problems. However, they focused on identifying the givens and had difficulty to understanding the problem itself. In addition, teachers from both years emphasised that students could not imagine the problem situation, which caused difficulties in understanding the problem.

Think aloud protocols were used to gain an understanding of how students solved mechanics problems. In the current study, all the interviewed students from both years were asked to think aloud about the solution to the following mechanics problem:

> A box weighs 562 Newton on a tilted surface at a 30° angle. The force of gravity has two components, one perpendicular and one parallel to the incline. Find the two components of the weight force.

The most noteworthy results that appeared through students thinking about the solution of the aforementioned mechanics problem are presented.

Despite the questions suggested by Polya (see section 3.3.5), one of the first-year students (TAPS3F) started his thinking with imagining the problem. After that, he used a drawing, but he could not find the unknown in the problem, because the solution required more than one step to reach the unknown:

> I'm…. mmm I'm trying to imagine the problem in order to define the coordinates. First of all, ahh, okay, this coordinate is X with sine of the angle 30, and another one is Y with cosine of the angle 30. *mmm…* then, this is the tilted surface, *mmm*…what I have to do now is to find the required point which is… *mmm…* Find the two components of the weight force, but..ahh, I do not understand this […]. I feel that the solution requires something based on something else and this is a difficulty that confuses my understanding.

Meanwhile, another first-year student (TAPS8F) began drawing a figure and wrote the problem data; he seemed to give much attention to understanding the problem but moved directly to find the suitable law:

> Okay, mmm, the first thing I do is draw the physics problem like this, and this is coordinate X, and this is Y. I'm…. Okay, and this is a box that weighs 562 Newton on a tilted surface. Mmm..., I think I need to look for the suitable law, but honestly, I do not know because I do not remember the law.

When asking a first-year student (TAPS7F) about his procedures in the previous mechanics problem, he mentioned clearly that he did not understand the problem although he started to imagine the problem in his mind:

> Well, I think about a box making an angle… nearly like that, and mmm…I'm supposed to find the weight…ahh, it is 562 Newton and… the gravity is its opposite. Ahh, but I do not understand this concept the two components of the weight force … mmm I cannot complete the procedures of the solution of this problem, because I found difficulty to understand the problem.

In the same context, a first-year student (TAPS10F) expressed his thoughts about understanding the problem in more detail compared with TAPS3F, TAPS8F and TAPS7F; he drew the diagram and analysed two components correctly, but he found the result of each component of the weight force and he did not calculate the total of components of the weight force:

> Firstly, I have a box on a tilted surface, mmm... let’s assume that this tilted surface and this box sits at an angle of 30 degrees and the weight... mmm is 562 Newton. Okay, I'm going to take the weight and multiply it by the sine of the angle 30, ahh, the result mmm... is 281 N. Okay, mmm... then I will find the perpendicular axis… ahh. I think with the perpendicular axis… mmm, I will take the weight and multiply it by the cosine of the angle 30 and, ahh the result mmm... is 486.71 N.

On the other hand, one of the preparatory students (TAPS16P) was given the abovementioned mechanics problem and could not solve it; he mentioned: “What is this? This is the first time to see like this problem, mmm…I do not understand the mechanics problem”. Also, a preparatory-year student (TAPS18P) was asked about how he thought through the solution of that mechanics problem and could not complete his thinking because he found difficulty in understanding physics problem and because he did not understand the concepts of this problem:

> I can see that the first part of the problem is understandable but, mmm… the second part poses a difficulty in understanding the problem, also the concepts of the physics problem. I mean that I do not understand ‘Find the two components of the weight force’ because it's the first time I hear this phrase. So, mmm…. I do not understand the problem clearly, ah… subsequently, I cannot think about the solution.

Similarly, a preparatory-year student (TAPS12P) mentioned that he faced difficulties thinking about this problem; he could not understand it, so he stopped thinking about the solution:

> First, umm... I can see now from the problem the data which is represented in the weight and ahh... the angle, umm... and the requirement is ‘find the two components of the weight force’. Umm…, through reading this physics problem, I do not get the meaning, I cannot think.

A preparatory-year student (TAPS11P) could not carry on thinking because he did not understand the problem: “umm …I think…umm … I am having trouble with this concept –the force of gravity– but what is this? …it’s the first time I have heard of it […] and I do not have any previous background”.

One of the noteworthy issues that appeared through the students’ think alouds was that they appeared confused between understanding the problem and devising a plan, and this was confirmed by other students from both years who mentioned that devising a plan is to search for the data while solving the mechanics problem. For example, a first-year student (TAPS6F) explained while attempting to solve the problem:

> Mmm, …I'm going to make a plan by finding the data which is 'weight=562 Newton' and the angle is… 30°…. The angle above is horizontal. Umm, after that…I need to find the directions of the force, mmm… I don't know.

Similarly, a preparatory-year student (TAPS2P) explained that devising a plan is to find the data from the physics problem, although he did not give much explanation about how he could understand the physics problem:

> Okay, my plan with this problem…umm is defining the data which is… ahh... the weight=562 Newton and…ahh... the 30° angle, then…mmm, I forgot what is the suitable law? … I do not know, sorry.

Also, during the interviews with two first-year students and three preparatory-year students (S9F, S21F, S14P, S15P, S20P) mentioned that devising the plan means searching for the data and physics laws. An example of this view was confirmed by a preparatory-year student (S15P): "devising a plan is finding laws and data from the problem".

Interestingly, students from both years during the think aloud protocols drew a diagram when they tried to solve the above problem; their diagram showed a lack of understanding of the physics problem whereby all preparatory-year students showed that they did not have a basic physics knowledge about "the two components of the weight forces" and could not draw the components of the weight forces correctly because they did not understand the concept (components of the weight force), as shown in Figure 6.3, whereas, the first-year students drew the components. This can be explained by the fact that first-year students can be considered as specialists in physics, unlike the preparatory-year students who do not specialize in physics, although the physics problem was taken from a secondary school physics book. However, first-year students (TAPS3F, TAPS5F) made a mistake when they tried to analyse the two components of the weight force on the diagram as they multiplied the weight by the cosine of the angle 30º on the perpendicular axis (see Figure 6.4) except five students (TAPS1F, TAPS4F, TAPS9F, TAPS19F, TAPS21F) who analysed two components correctly, but did not solve the problem because they did not understand what to do next.

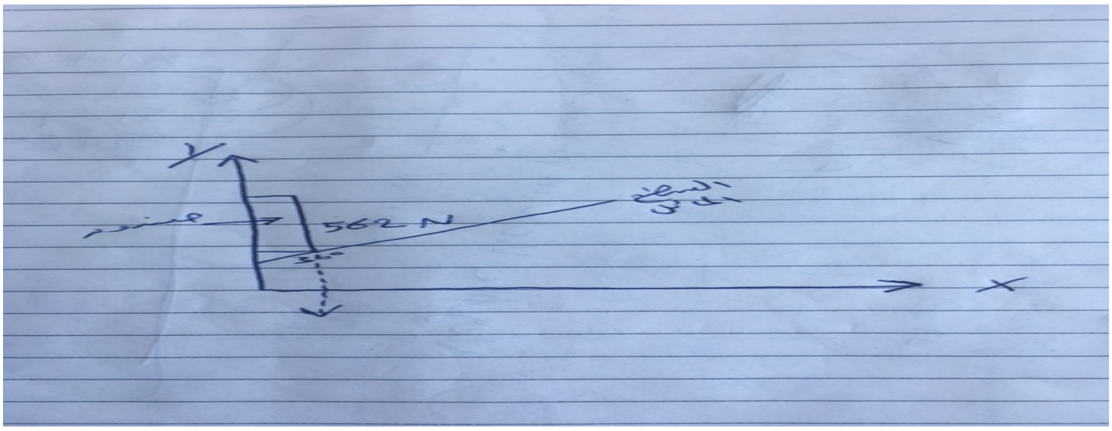

Figure 6.3: A preparatory-year student's response to the physics problem (TAPS18P)

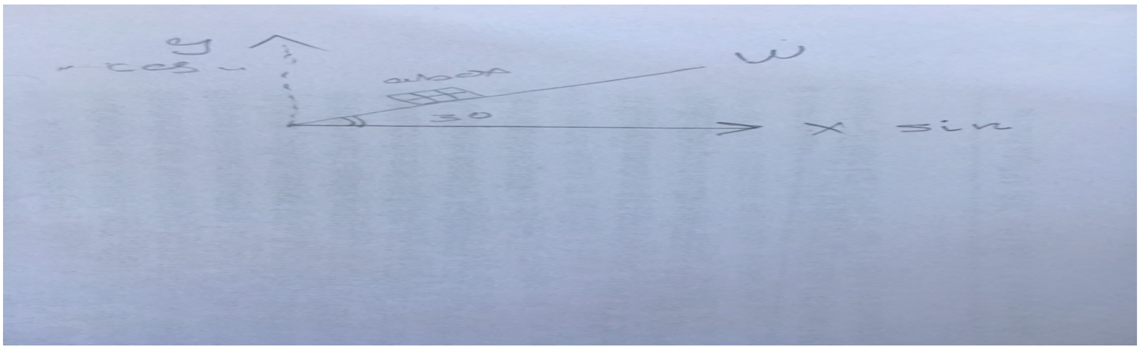

Figure 6.4: A first-year student's response to the physics problem (TAPS5F)

Moreover, while conducting classroom observations, it was noticed that all the teachers questioned their students' questions while solving mechanics problems, such as "what is the unknown? What is the given part? What is the relation between the data and the missing part?" However, it was also noticed that the teachers asked such questions without giving students the opportunity to think so teachers often answered the questions themselves. The exception to this was in classroom observation O8P where the teacher discussed the comprehension of the mechanics problem with his students by using a graph to clarify the requirement. Also, he checked the students' understanding through asking certain questions, such as, "what is the unknown in the physics problem?" or "what are the data in this problem?"

Also, during the interviews, four preparatory-year students and five first-year students indicated that one of the difficulties in mechanics lessons was that the problems need a sort of thinking. This was highlighted by a first-year student (S6F): "for the mechanics problems that are given to us, the method of understanding is considered difficult, meaning that it needs a sort of understanding the physics concepts". Another first-year student (S7F) agreed with S6F about the difficulties he faced with respect to imagining the problem in order to understand it: "physics problems are all imaginative, so, I think that the syllabus of mechanics is difficult. The reason is that is that I see these problems for the first time in my life and because they have more than one dimension, it's difficult for me to understand the mechanics problem". In the same context, a preparatory-year student (S18P) confirmed this aspect: "the part related to mechanics, it contains a sort of difficulty to understand the dimensions of the mechanics problem and comprehend it". Meanwhile, one of the preparatory-year students (S15P) indicated the relationship between the difficulty of a problem and understanding, which affected negatively his comprehension and therefore affected his understanding of the problem:

> The difficulty of mechanics problems makes me understand incorrectly, as a result, when I want to draw a graph to understand the physics problem, I draw wrong and thus I cannot understand very well.

During the interviews, all the teachers indicated that the students had difficulty in comprehending physics problems from multiple perspectives. These perspectives are related to the fact that students do not give enough focus to understanding physics problems and to training and guiding students to understand physics problems. For example, a first-year teacher (T4F) mentioned the imagination and its role in getting students to understand a physics problem:

> The students have difficulty with mechanics and coordinates. This is reflected in their understanding of the mechanics problem because it depends on imagination, and imagination is the hardest [....]. Although, the student in this phase has become mature in terms of his thinking.

Also, in the same context, one of the preparatory-year teachers (T9P) agreed with T4F and stated that the reason for the difficulty in understanding was imagination because mechanics problems require students to think and imagine: "the mechanics problems which contain a sort of imagination cause difficulties to the students in terms of understanding the problem". This was also confirmed by a preparatory-year teacher (T5P) who stated clearly that the issue faced by students is understanding a physics problem: "the students' problem is in defining and understanding the problem; they should be trained and directed on this point. The teacher here may play a role in this".

In the same context, a first-year teacher (T4F) was critical about students who do not pay attention to understanding the physics problem: “the student’s problem is that he doesn’t focus on understanding the mechanics problem. He must ask a lot of questions to reach the solution”.

On the other hand, it seems that a preparatory-year teacher (T2P) did not notice that his students have a problem in understanding physics problems except in the laboratory:

> I found that the student has a problem in understanding when we observe group work in the laboratory. In this regard, the student doesn’t know what is required from him. When we ask him, it becomes obvious that the student doesn't understand the physics problem.

The above quotes reflect the perspectives and opinions of the students and teachers from both years regarding the understanding of the problem. Students’ thoughts during the think aloud were also highlighted. These quotes showed that students have difficulties in understanding physics problems. The difficulty of imagining the problem was one of the barriers which prevented students from understanding the problem. As mentioned above, students seemed confused between understanding the problem and devising a plan. The next problem-solving step highlighted by the data is *devising a plan*.

6.3.2 Devising a plan

Through conducting interviews with all students and based on think aloud protocols using the same mechanics problem given above, the results show that the students did not seem to know how to devise a plan to solve the problem given to them. Also, through the analysis, it appeared that they have the perception that extracting the data and finding the required part from the mechanics problem is considered to be devising a plan. In this section, the results that confirm this point are presented.

For example, through the interviews, one of the first-year students (S7F) was asked how he would deal with an unfamiliar problem in mechanics and he mentioned clearly that he would not devise a plan: “we directly start solving without any planning for the solving method, because we are not accustomed to that through our studies”. In the same context, a first-year student (S1F) held similar views about the fact that he does not give attention to devising a plan: “I try to solve it and I write it quickly fearing that I might forget it. So, I solve it quickly without planning because I still remember it in my mind, and this is due to my fear of forgetting it". When the previous mechanics problem was given to the first-year student TAPS5F, he clearly mentioned, during the think aloud, his difficulty in devising a plan to solve the problem:

> Umm…I cannot solve this problem, ahh… I can see the data is easy for me but …. mmm… devising a plan to solve this is difficult for me. Maybe the box will be on a tilted surface like this,…mmm I think, … I need to multiply the weight by the sine of the angle 30^{o} on the horizontal axis, and the cosine of the angle 30^{o} on the perpendicular axis. Frankly, mmm… I do not know how to continue solving this problem, because the idea isn't drawn in my mind correctly.

One of the preparatory-year students (S15P) was asked during the interview about how he could plan to solve a physics problem and he talked about making the plan is searching for the data and physics laws: "devising a plan is finding laws and data from the problem".

From another perspective, during the interviews, a first-year student (S10F) felt that a student's practice in solving mechanics problems plays a vital role in planning during solving: "I see that if the practice of the student is not strong, he won't be able to apply the plan correctly". At the end of the interview with one of the first-year students (S19F), when asked if he wanted to add anything, he said that teachers should engage students with him in solving physics problems in order to show them how to devise a plan: "teacher should involve the students in the solution; he should explain to them how it could be planned to solve any mechanics problem, and that would have made it easy for us to solve".

Through all the classroom observations, it was noticed that teachers did not focus on planning but on data extraction, on the requirements of the problem and on the direct application of the law without providing any time to devise a plan for the students to follow. It was also noticed that teachers explained fairly quickly when discussing mechanics problems. Observation O8P was an exception to this as the teacher was asking his students a set of questions such as "What does the requirement of this problem remind you of? Let's apply the given data to know the missing part".

All the teachers indicated that the students had no clear method in the solving process. Of their highlighted answers which clarify this, for instance, a first-year teacher (T4F) indicated: "the most difficult thing for the student is to begin solving the problem, what is the way that will help him reach the solution". Meanwhile, one of the first-year teachers (T1F) saw that students are not accustomed to making a plan when solving physics problems: "the way in which a student defines a method to follow while thinking of the solution of the mechanics problem […] is a new thing for students to which they may not be accustomed". Also, a preparatory-year teacher (T3P) explained in more detail why students are not accustomed to making a plan when solving physics problems and he blamed schools for this:

> The student, since school, has not properly learnt how to think or devise a plan for his method of solving, but they have destroyed him and made him accustomed to memorization. They give him mathematical or physics problems and tell him that the test will consist of the pre-defined parts of the syllabus, and I consider this a betrayal.

The above data from the participants show that students lacked the skills of planning in problem-solving, and they did not seem to understand how they could plan to reach the solution of the physics problem. In the next section, the third problem-solving step is presented, that is, *carrying out the plan*.

6.3.3 Carrying out the plan

Through students' think aloud protocols using the mechanics problem given to them, and as mentioned in the previous section (devising a plan), students have the perception that extraction of the required data from the mechanics problem was considered as part of devising a plan. Also, it has appeared from the analysis of the data that the students did not seem to know how to devise a plan for the problem given to them. Subsequently, from the statements of the participants through the think aloud protocols, there was no clear indication that they were carrying out a plan to reach the solution of the problem. Indeed, after thinking about the previous mechanics problem, students were asked how they were carrying out a plan to complete the mechanics problem. Five first-year students and four preparatory-year students (S1F, S3F, S6F, S9F, S9F, S2P, S11P, S13P, S20P) saw that to carry out the plan is to apply equations to obtain the solution. In the same context, a preparatory-year student (S18P) indicated that he believed that carrying out the plan is "applying the law". In this respect, he considered that carrying out the plan would be easy for him if he practiced similar physics problems: "the application can be problematic because if I have never solved a similar problem, there would be a problem in application”. Also, three first-year students and a preparatory-year student (S4F, S8F, S12F, S12P) believed that the collection of information about the problem is carrying out the plan. Whereas, three first-year students and four preparatory year students (S5F, S10F, S19F, S12P, S14P, S15P, S16P) did not know about this step. In the next section, the data relating to the fourth problem-solving step is presented, that is, *looking back.*

6.3.4 Looking back

The student participants in both the preparatory and first-year, when presented with the previous mechanics problem, did not demonstrate that they implemented this step (looking back) in their problem-solving. An exception to this was a first-year student (S9F) who, when discussing the solution during a think aloud, mentioned: “Umm, it appears to me that the result I reached from this problem is too large for the data”. In addition, through classroom observations, this step was not apparent in the teachers’ explanations of the solution of the mechanics problems. This comes with the exception of classroom observation O8P where the only evaluation aspect used by the teacher was checking that the measuring units used in the solution made sense or not, which he discussed with the students.

Based on the above results (section 6.3) it appears that students get confused between devising a plan and understanding the problem and did not seem to know how to devise a plan to solve the problem. As for carrying out a plan and looking back, the students think aloud did not demonstrate evidence of this. In the next section, the data shedding light on the third theme are presented: *lack of basic knowledge at different levels of the education system* and how this lack affects students' learning to solve physics problems.

6.4 Lack of basic knowledge at different levels of the education system

The data show that students’ lack of basic knowledge acquired from school and university was due to three reasons: (1) lack of basic physics knowledge, (2) lack of basic physics conceptual understanding, and (3) lack of basic mathematical knowledge, as Figure 6.5 shows.

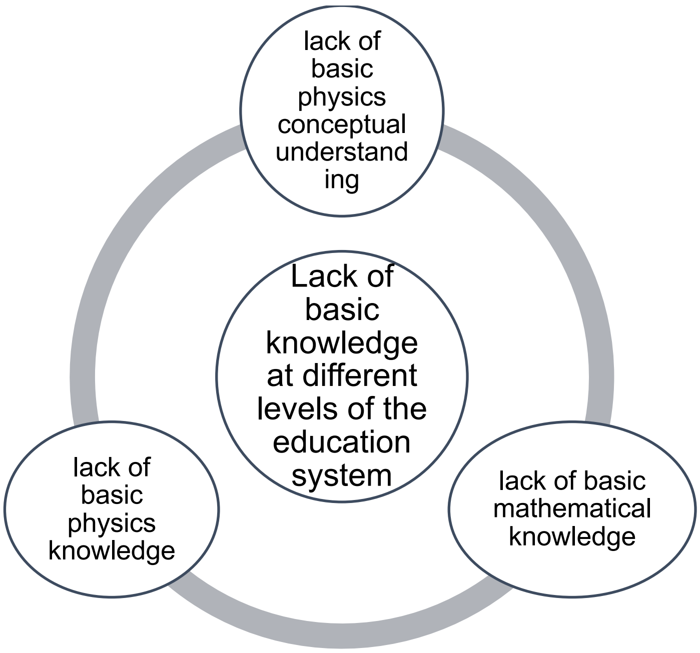

Figure 6.5: Lack of basic knowledge at different levels of the education system

6.4.1 Lack of basic physics knowledge

With regards to the school level, all preparatory- and first-year students discussed the lack of basic physics knowledge acquired from school that reflected negatively on their understanding of physics and their approach to solving physics problems. For example, a first-year student (S6F) confirmed this point:

> My lack of knowledge in physics in general is weak and now I'm trying to develop myself, the problem is that I reached college with a lack of basic knowledge. As a result, I cannot follow the teacher in his explanation because there are physics matters that stop me as I cannot comprehend them due to weak basic knowledge [....] so I wish that I could repeat my studies once more, primary, intermediate and secondary school, to understand when I reach the university.

Another preparatory-year student (S18P) mentioned that the reason behind the lack of knowledge relates to the fact that students in schools were accustomed to memorising rather than using thinking:

> I face a physics problem in general or a mechanic problem in particular, I find it difficult and this is because of the lack of basic knowledge from school, as we got used to memorizing the rules and applying them directly without challenging our thinking.

Besides, a preparatory-year student (S16P) viewed this matter from a different perspective as he indicated that private schools affect the lack of basic physics knowledge. He felt that he did not receive good basic physics knowledge from school which made him hate physics and he explained the reason for this: “I studied in a private school and I found that I have a weak foundation in physics, and I can honestly say that private schools are considered to be destructive for general education”. He also stated that, if he was responsible for general education, he would “eliminate private schools because they are destructive to people and generations”. He added: “as for the city of Taif, I can say that 80% of private schools are harmful to the student, unlike government schools”.

One of the first-year teachers (T7F) agreed with a preparatory-year student (S16P) about how the private schools affect students in regard to the lack of basic physics knowledge

> In college, students who studied at private schools come to us and you find that the student had a 100% final grade in secondary school test while the fact is that he didn't open a book, and this is a crime at the student’s right […]. So, the matter of student basic physics knowledge in general education should be considered.

In the same context, one of the preparatory-year teachers (T2P) indicated:

> Some students come to us from private schools and, as is known, its goal is financial not educational, […] so you are surprised in physics that the student does not have a clue how to calculate. Imagine that some students have never used the calculator before!

One of the thought-provoking and surprising issues encountered during classroom observations in the preparatory-year (6P) occurred when the teacher asked a student to solve the following mechanics problem on the board related to the laws of kinetic energy:

> Masses of 6.0 kg and 2.0 kg are connected by a light inextensible string passing over a smooth pulley. The string is taut when the masses are released. The smaller mass accelerates upwards and the bigger mass accelerates downwards. Using the Principle of Conservation of Energy, calculate the speed of the masses when the larger one has descended 2.0m.

The student stopped and did not solve the physics problem, so the teacher asked: “Why could you not solve the problem while you have previously studied the laws of kinetic energy in secondary school?” To this, the student replied: “we did not study these points”, so the teacher was surprised and said, “didn't you study physics at the third grade of secondary school”. The student replied, “we did not study physics”, so the teacher asked the student in surprise, “How did you graduate from secondary phase and enrol in college?”, so the student became quiet and did not answer this, and I tried to do an interview with this student, but he excused himself from it.

One of the first-year students (S10F) believed that school is a fundamental element to give students basic physics knowledge:

> I think that school is the greatest sorrow in the life of any young Saudi in regard to the problem of the lack of basic physics knowledge. You rarely find a student who has benefitted academically […]. For me, I did not benefit from the school in terms of getting basic physics knowledge.

At university, a preparatory-year student (S15P) indicated that teachers believe that students have basic knowledge about physics problems from school; therefore, the university teacher might not pay more attention and explain some mechanics problems, which will be reflected negatively in students' understanding in physics:

> There are some mechanics problems or physics problems in which the teacher thinks the student has a basis; the teacher doesn't explain in detail, but he settles for a brief explanation. Consequently, the student finds them difficult.

In this regard, a preparatory-year teacher (T5P) agreed with the above student (S15P) about the fact that the teacher believes that students have basic physics knowledge: "When explaining a physics problem, I rush through some points believing that the student has basic physics knowledge".

A number of participants in the preparatory and first-year indicated that they have not gained a sufficient basic knowledge in secondary school regarding thinking and problem-solving skills in physics. For instance, one of the first-year students (S8F) indicated that he had not been prepared in secondary school for thinking and problem-solving skills while studying physics: "as in secondary school, most students don't care enough about thinking and problem-solving skills included in physics books or it is considered unnecessary". He also mentioned the reason behind that: "Our interest was how we could get the highest grade in secondary school tests, […], also the teachers in some cases do not focus on those skills or do not understand how to apply them, for example, the steps of problem-solving in dealing with the solution of mechanics problems". Concerning the relationship between the lack of basic physics knowledge of students and their thinking, a first-year teacher (T6F) declared: "A lack of basic physics knowledge from school influences the level of students' thinking when they want to understand solving problems in physics".

Referring to the lack of basic physics knowledge from school, one of the first-year teachers (T7F) told a story about one of his sons who was studying in secondary school. The teacher recounted that when he asked his son to revise physics lessons and he replied: "Why should I revise my lessons, Dad, while the teacher will give us summaries of the semester and I will get high grades?" He also said: "Why should I refer to the book and burden myself?" and so this teacher questioned:

> Who commits this crime at the student's right? It's the teacher, so when a student comes to us in the preparatory-year and doesn't know what is Pythagoras Theorem or the basics of multiplication and division, you find an incomplete syllabus has been given to the students, and there is omission of some lessons. Of course, not all the teachers are like this, but there are teachers who are good and care about their students. I'm only telling you what's happening with my son.

As for the curriculum taught to the students in secondary school, one of the preparatory-year teachers (T9P) indicated that the curriculum is good, but the teacher stressed the importance of basic physics knowledge which students should acquire from school:

> I see the necessity to focus on the issue of basic physics knowledge in school because it's the reason of students' delay in academic achievement. The curriculum taught to the students is quite good but what has been offered and absorbed by the student are only shreds of this.

Two teachers in the first-year and a preparatory-year teacher (T10F, T7F and T5P) mentioned that the matter of continuous evaluation in school is catastrophic for the student because the student succeeds in the syllabus with no mastery, which leads to a weakening of the student's basic scientific knowledge and influences his learning and understanding of physics. It is worth bearing in mind that continuous assessment is applied in primary schools, so that the level of the students depends on how familiar they are with the basic knowledge and skills as defined by the curriculum designed by the Ministry of Education. In this regard, the teacher always writes his observations about the student's performance and development in learning science, knowledge, skills and the difficulties he may face. The decision to pass a student from one stage to another is based on the student's ability and attainment of a minimum level of science, in terms of knowledge and basic skills as defined by the Ministry of Education (Continuous Evaluation Guide, 2009).

Furthermore, with respect to the university level, the results of the interview analysis of teachers in both years (T8P, T1F, T7F and T10F) revealed the weak basic knowledge of preparatory-year students in physics and also the weak basic knowledge of first-year students in mechanics. For example, one of the preparatory-year teachers (T8P) emphasised that the level of a student in terms of basic physics knowledge is weak and that this is reflected in the level of pre-service teachers in school and, in turn, in the student's level: "the student graduates from university with weak basic physics knowledge and then works in the field of education. This negatively influences the teaching of the coming generations and so on". Meanwhile, a first-year teacher (T1F) also spoke clearly about the lack of basic physics knowledge compared with other students in other specialties:

> I teach students of computer science, engineering and physics specializations, and the weakest of all of them are those of the physics speciality. [...] the level of students of physics is below the level of a university student in relation to basic physics knowledge.

In the same context, a first-year teacher (T7F) was critical about the level in the preparatory-year when students move to the first-year in relation to their levels in basic physics knowledge: "In the physics department, the worst students in terms of their grades in the preparatory-year who have a lack of physics knowledge come to us". He also emphasised that a physics pre-service teacher who graduates from the university has a lack of basics physics knowledge which can affect students' understanding, as what happened with his son in secondary school:

> My son was studying at the secondary level and there was a physics pre-service teacher from Taif University who taught students the physics. Once upon a time, the pre-service teacher said that the unit of wavelength measurement is the Hertz, and my son told him the unit of wavelength measurement is not the Hertz, and the pre-service teacher got laughs with mockery and said to my son: Are you better than me?

Another aspect of the data showing the students' lack of basic physics knowledge acquired from university is that a number of teachers mentioned that the academic standards of physics students over recent years have been weaker than in the past. For instance, a first-year teacher (T10F) confirmed:

> The level of physics students 12 years ago was much better than at present. Now, the curve of physics students' level is descending, and not ascending. The student's only concern is to pass so you find the students after examination throwing their books and summaries in the street or in the corridors and forget what they have learned during their years of study, and this is the biggest disaster.

The following section shows another side of the data revealed by the study, which is one of the important aspects influencing students' understanding of physics: *lack of basic physics conceptual understanding*.

6.4.2 Lack of basic physics conceptual understanding

A number of students from both years and two preparatory teachers referred to students' lack of basic physics conceptual understanding while solving physics problems in general and mechanics problems in particular. For example, a preparatory-year student (S17P) mentioned:

> I don't comprehend the physics concept, but I memorize it with no deep comprehension of that concept, because some teachers don't clarify the physics meaning enough that allows us to comprehend.

Confirming this, while conducting class observations (O3F), there were a number of physics concepts related to force types which the teacher did not clarify, for instance the concepts of conservative and non-conservative force. Also, in another observation (O5F), when the teacher solved the following mechanics problem: "In the Cartesian coordinate system, find the equation of both instantaneous velocity and instantaneous acceleration". It had not been discussed with the students whether the concepts in the mechanics problem were clear or not. This was confirmed by other classroom observations (O1F, O6P, O7P, O9P, O10P) whereby it was noticed that teachers seemed not to focus on physics concepts during their teaching and did not make sure of whether or not these concepts were understood. One of the first-year students (S3F) clarified the reason for teachers not discussing these physics concepts or offering a more detailed explanation by stating:

> To be honest, my knowledge about physics concepts in general is superficial, and the teacher thinks that we have a fair basis about the mechanics physics concepts, so while the teacher progresses rapidly through the explanation, I keep thinking about the meaning of this concept during solving physics problems.

Also, the following mechanics problem was given to the students who were interviewed:

> A box weighs 562 Newton on a tilted surface at a 30-degree angle. The force of gravity has two components, one perpendicular and one parallel to the incline. Find the two components of the weight force.

Then, they were asked to think aloud through the solution of this problem, but they seemed to have a lack of basic physics conceptual understanding, which was confirmed by other students from both years:

> Ok, I'm going to draw the diagram of the problem, but…mmm… what are these concepts? The force of gravity and two components of the weight force, I do not understand this, umm, I haven't heard about it before. (S11P)

Moreover, two preparatory-year teachers mentioned during the interviews the lack of basic physics conceptual understanding. For example, T3P believed that the cause of students' confusion in understanding physics concepts was the lack of basic physics conceptual understanding: "students are generally confused in their understanding of physics concepts as a result of a weak basic physics conceptual understanding".

One of the first-year students (S1F) agreed with T3P about the lack of basic conceptual understanding: "a lack of basic conceptual understanding of physics concepts in general and mechanics in particular, especially the abstract concepts, causes difficulties in solving mechanics problems".

Regarding the similarity of physics symbols and its influence on students' understanding, two first-year students and one preparatory-year student indicated that this issue played a vital role in their understanding of mechanics problems. For example, one of the first-year students (S6F) indicated that what caused him difficulties in solving mechanics problems was the similarity of the symbols for physics concepts and that this affected his understanding:

> In reality, there are similarities between physics concepts' symbols. In the mechanics syllabus, the concept of work is referred to with the symbol *W* and the weight with the symbol *W.* So, when the teacher solves a mechanics problem on the board, he doesn't put these symbols on the side of the board with their meanings. So, I remain confused thinking of the meaning of these symbols. While the teacher is completing a huge part of the explanation, I am still thinking of the meaning of this symbol.

Furthermore, through classroom observations 8F and 5P, it was found that students confused the symbols used in the solutions. A number of students answered one of the teacher's questions concerning the X symbol. Some said that it represented the concept of distance and others said it represented the concept of displacement.

A factor influencing students' understanding in solving physics problems is the multiplicity of physics concepts. A preparatory-year student (S14P) indicated: "when I see the multiplicity of physics concepts and the difficulty of understanding them on the board, this is considered the biggest factor affecting my understanding to solve physics problems".

6.4.3 Lack of basic mathematical knowledge

Ten of the student participants (four preparatory-year students and six first-year students) mentioned that another important aspect regarding the lack of basic knowledge is represented in the notion that most difficulties facing students while solving physics problems are caused by the lack of basic mathematical knowledge. This was one of the most frequently highlighted issues revealed by the results. For instance, one of the first-year students (S3F) stressed the importance of basic mathematical knowledge in order to solve physics problems and acknowledged his own shortcomings in mathematical knowledge: "the student should have a good basis in mathematics to be able to figure the mechanics problems. As for me, I have issues and weaknesses in mathematics". Also, one of the first-year students (S19F) was critical about his foundation in school regarding basic mathematical knowledge and agreed with S3F about weaknesses in mathematics:

> Our preparation in school was shallow without depth in mathematics and this reflected on our understanding of physics problems [....]. This confirms that we have weaknesses in mathematics. When we reached the university, we studied calculus and every student in my class failed except for three or four out of sixty students.

One of the preparatory-year students (S15P) saw the importance of mathematics knowledge in physics and clarified the mathematical difficulties he faced while solving mechanics problems:

> Mathematics knowledge is considered very important in physics, but for me multiplication and division and other mathematical calculations which require a calculator while dealing with solving physics problems cause difficulties to me.

In the same context, a first-year student (S1F) indicated that some mechanics problems require the use of complex and difficult mathematical concepts such as calculus, when trying to solve physics problem and he believed that the difficulties which he faces in mathematics are due to a lack of basic mathematical knowledge:

> I find myself focusing on the mathematical parts because of their difficulty and forget about the important part which is figuring out the problem from a physics perspective, and this is because of my lack of basic mathematical knowledge over previous years.

In the same context, all of the teachers confirmed that their students lack basic mathematical knowledge. For instance, a first-year teacher (T4F) mentioned: “40% of the obstacles students face are represented in lack of basic mathematical knowledge received in mathematics throughout the previous years”. On the other hand, one of the teachers from the preparatory-year (T3P) emphasised that the students in both years have a lack of basic mathematical knowledge, although he stressed the importance of basic knowledge in mathematics to solve physics problems. He believed that if the physics department took into account this condition (having basic knowledge in mathematics), no student would be accepted in the physics department:

> The level of physics students in both the preparatory-year and first-year in basic mathematics is very poor concerning the basics. From my point of view, to be able to deal with solving physics problems, the student should have a basic background in mathematics. But if this requirement is followed, then no student will be accepted in the physics department. So, we, in the physics department, set minimal acceptance grades for instance in mathematics and physics to be able to accept the students.

One of the first-year teachers (T1F) saw, from his point of view, that the reason behind students’ dislike of physics was related to mathematics, and he believed that the level of students in mathematics was weak:

Students need to get solid knowledge in mathematics, because it is crucial to solve physics problems. Unfortunately, the students’ basic knowledge in the mathematical aspects is poor and this is one of the reasons that make the students repulsed by physics because it depends on mathematics.

Furthermore, through classroom observation (8P), it was found that students in discussion with the teacher made errors in calculations, such as the conversion from metre to centimetre or from multiplication to division.

All the teachers agreed that the students have weaknesses in dealing with mathematical issues when approaching mechanics problems. For example, a preparatory-year teacher (T5P) mentioned: “students have, for instance, difficulty in figuring out when to use vector product and scalar product while dealing with solving mechanics problems”. In the same context, T2P stressed the fact that mathematics was a common difficulty faced by students in solving physics problems: “what we find most difficult with our students are mathematical matters. The students have a lack of basic mathematical knowledge and difficulties and are unable to do mathematical calculations when solving physics problems.”

Based on the above, it appears that there is a consensus among participants, whether students or teachers in both years, that a lack of basic physics knowledge results from several factors arising from the school and the university. Hence, the students are weak in terms of the conceptual aspect of physics. Also, difficulties are encountered by students when dealing with physics problems which require them to use mathematical skills. In the next section, the data will shed light on the dynamics of the physics classrooms in relation to how teachers teach physics problems and how they encourage their students to think effectively. Therefore, the findings relating to the fourth theme are presented: *perspectives on physics teaching methods*.

6.5 Perspectives on physics teaching methods

Through the interviews conducted with the participants, and the classroom observations, with respect to the teaching methods used in physics several aspects emerged from the data, as follows: (1) the interaction between the teacher and his students and among the students themselves, (2) physics teaching methods in the university, and (3) physics teaching methods in schools, as Figure 6.6 shows.

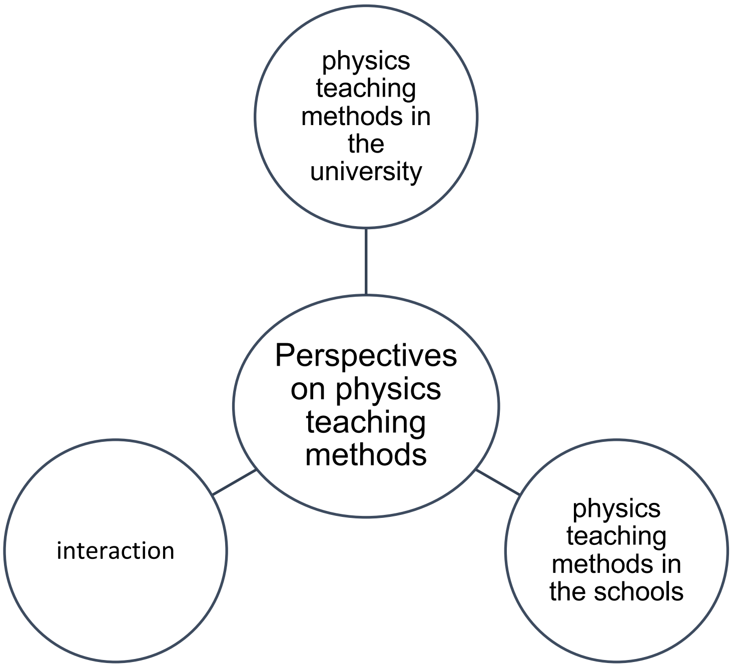

Figure 6.6 Perspectives on physics teaching methods

6.5.1 Interaction

Through analysing the interviews of the students and the teachers in the current study, half the participants of both years of students indicated that interaction between the teacher and his students or among the students themselves is almost non-existent, except one of the students who mentioned that the reason he enjoys physics is the discussion between himself and his teacher and also with his classmates. In this section, the results of both the interviews and classroom observations will be presented regarding interaction, as shown below through the responses of the participants.

For instance, a first-year student (S19F) stressed that there should be some sort of participation and interaction between the student and the teacher while solving physics problems on the board:

The teacher should create a sort of interaction and participation with him while dealing with mechanics problems, and make the student participate with him on the board instead of his traditional method.

Another first-year student (S10F) stressed the role of the teacher on students' learning of problem-solving in physics by explaining:

If there was enthusiasm from the teacher, this would have helped us to interact with the teacher, but the fact is, that here in university, there is nothing makes us want to interact and understand in solving physics problems.

Also, a first-year student (S4F) thought that the teacher doesn't allow for participation in class because of the lack of time: “the teacher doesn't make room for us to participate with him because he only wants to explain his lecture and it might be because he doesn't want to waste the lecture time”. While asking a first-year student (S7F) about how he solves difficult mechanics problems with his classmates, he answered:

> Student participation in solving mechanics problems in class is almost non-existent because the teacher does not allow it. The teacher explains all the time on the board and the students are mostly listening to his explanation.

A preparatory-year student (S13P) spoke clearly about the lack of students’ interaction in physics lectures:

> Students in physics class don't care about the lecture, they are browsing their mobile phones. This is due to students do not find anything encouraging them to interact with their teachers; therefore, they won’t think about anything else.

On the other hand, a preparatory-year student (S20P) indicated that an aspect of the class environment caused weak interaction among the students. What he felt was missing was the conversation with his classmates through co-operative learning, which he had experienced when studying at Jeddah University, as he explained:

> Here in Taif University, there is no dialogue between us as students; however, in Jeddah, the shape of the class was circular, and we were working as groups and discussing; as a result, we understood physics better.

At the end of the interview, a preparatory-year student (S18P) stressed that one of the reasons behind the lack of students’ concentration during the lecture (not the practical lessons) was the absence of interaction: “the theoretical lecture in physics that doesn't include interaction and discussion is boring for the students, which makes us lose focus”.

These opinions were confirmed through classroom observations of both years. For instance, it was observed that (O2F) the teacher asked his students to solve the following mechanics problem with him on the board:

> A small block of wood passes through point P at a speed of 2.00 ms^{-1} and slides down a smooth curved track towards point Q.

(a) Calculate the speed of the block as it passes point Q, 12.0 m perpendicularly below P.

(b) Explain why it would be inappropriate to use Newton's equations of uniform acceleration in this situation.

(c) Does the time taken to travel from P to Q depend on the equation of the curved slope? Explain your answer.

However, none of the students responded to this problem. The teacher asked one of the students to solve the problem, but the student refused, and the teacher tried to find another student, but students did not respond and at the end, the teacher forced one of students to participate in solving the mechanics problem, and there was nothing done by the teacher to encourage participation. Also, in two classes, it was observed (O7P; O3F) that the teacher read the mechanics problem, wrote the data and then started to solve it on the board with no participation or discussion with the students. Likewise, it was noted (O1F) that only four students participated in the discussion with the teacher out of a total of 37 students. The rest were not following the teacher and were occupied with their mobile phones or sleeping while others chatted with their classmates about topics irrelevant to physics and the teacher did not take any action to keep their attention during the lecture. Also, it was observed in lecture (O10P) that seven students were sleeping, and that only six students participated in the discussion with the teacher out of a total of 33 students. Also, it was noted that the teacher did not encourage students to interact with him during solving physics problems on the board.

In contrast to the aforementioned participants' opinions, one of the first-year students mentioned that he participates with his teacher and mentioned that he enjoyed physics when he participated with his teacher: "I enjoy physics when I discuss with the teacher" (S8F). Also, he mentioned that he and his classmates meet outside the class: "we discuss with each other about the mechanics syllabus and that's what helps me to develop my thinking". In addition, during the classroom observations (O5F) I tried to focus on that student (S8F) and I found that he was trying to pay attention to his teacher and he was always asking questions if he did not understand, and he seemed to be eager to learn, unlike other his classmates.

On the teachers' side, half the participants from both years confirmed that the level of student participation and their interaction during the lecture was weak.

For instance, a preparatory-year teacher (T8P) mentioned that he noticed the number of students who participate in his physics lectures:

> A very small number, asks and participates, roughly three or four students from a total number of 60 students. The rest are not participating and might be even mentally absent during physics lectures, busy surfing their mobile phones.

Also, one of the first-year teachers (T4F) indicated that he wanted his students to interact with him in solving physics problems and mentioned that he would be satisfied with one question from his students but indicated: “the physics students in Saudi Arabia don't discuss or ask questions, unlike the case when I was in my country. I honestly am satisfied with only one question from the students, I’m really tired”. A preparatory-year teacher (T5P) agreed with T4F regarding the students’ lack of interaction with him in physics lectures and mentioned clearly that “the physics students’ pessimistic nature means that they do not interact with [him]”.

However, it was noted from the analysis of students’ interviews in both levels (preparatory- and first-year) that more than half of the participants (12 in total) confirmed the importance of a friendly relationship between the teacher and the students in physics explanation, which in turn affected their thinking, interaction and learning. In this respect, a first-year student (S3F) was critical of his teacher during physics lectures and the way he deals with students, because he did not respect students’ questions and the student believed this to affect his understanding of physics problems negatively:

> If I try to ask my teacher about a specific point about a physics problem, he scolds me. This is a dilemma which damages the student psychologically and influences our understanding of physics problems negatively; those teachers make up 60% of the faculty. This happens even when the student tries to work hard, so I gave up asking him again.

However, a first-year student (S6F) complained about the teacher’s anger especially when he wants to ask questions in the mechanics lectures: “the teacher sometimes is angry when he comes to the mechanics lecture, and if I ask him, he gets upset, so I get afraid to ask him again”. One of the first-year students (S21F) narrated his story about a teacher’s dealing when solving mechanics’ problems; he explained that if the teacher establishes a friendly relationship with his students, this will be reflected in students’ learning of problem-solving in physics:

I asked him about one of the mechanic problems and he got angry, so I never attended any of his lectures after that. He kept telling me you're asking primary school questions. He got angry with me in front of my classmates and told me never to attend my lectures again if I asked about things that I should have already learnt in previous years, so the teacher needs to establish a friendly relationship with students in order to give us the opportunity to think and create a positive atmosphere.

While observing a first-year mechanics lecture, the teacher wrote the following problem on the board, as shown in below Figure (the lesson was about kinetic energy), which appeared to be too difficult for the students, so the teacher’s reaction seemed unreasonable.

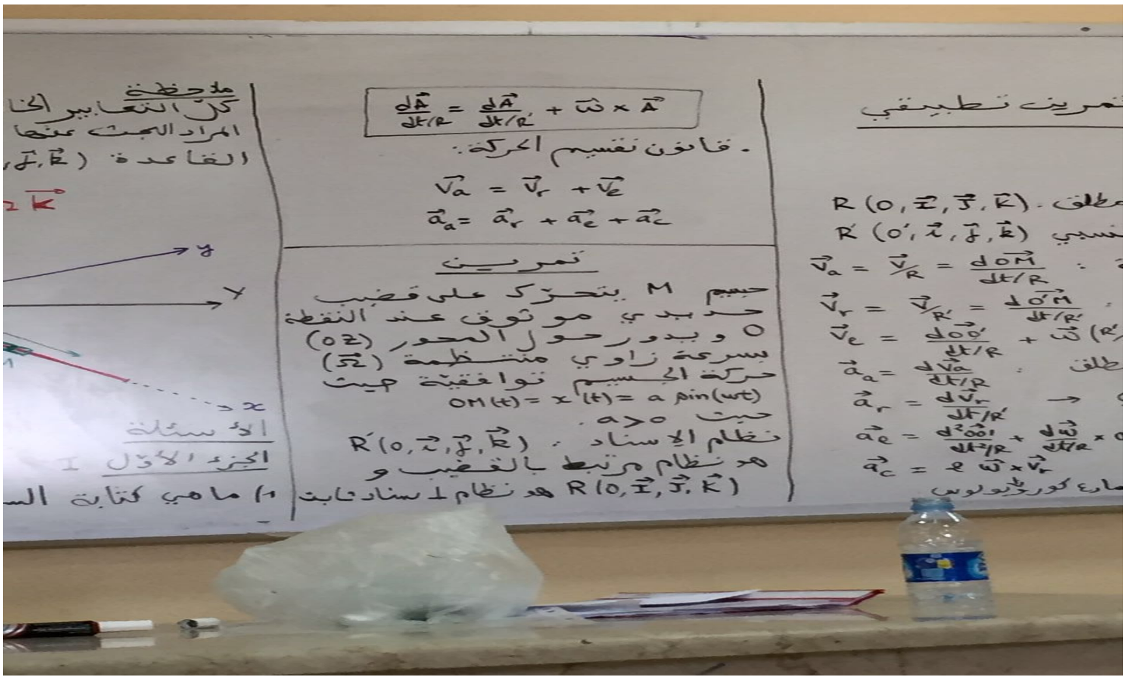

Figure 6.7: Whiteboard in the physics lecture (picture taken during an observation)

It was noted that when the teacher asked one of the students to solve the mechanics problem on the board, he got angry with the student because he made a mistake in the solution and the teacher did not use positive words to encourage the student because of his participation (OF2). One of the first-year students (S5F) talked about his suffering and the reason of his hatred of physics due to the way the teachers deal with their students in lectures:

Honestly, the teachers here at the university made me hate learning physics to an extent that I even stopped attending lectures or interacting during lectures, to the extent that I arrive on the examination day, come to the examination hall and return without entering to attend the exam. I feel that I’m psychologically damaged, and this is because of a teacher’s

> dealing with me during my studies in physics at the university. He made me hate physics.

Preparatory-year students indicated that the authority of the teacher sometimes made them disrespect the students, who prefer not to ask their teachers because they are afraid. This was confirmed by other preparatory-year students (S2P, S11P, S14P and S18P); for example, S18P said:

> Sometimes, a physics teacher embarrasses the student in front of his classmates, because the teacher has 100 grades in his hand, so he threatens the student with these grades and that is a problem at the university which makes students fear to ask or think in physics lecturers.

In addition, a preparatory-year student (S12P) clearly indicated that the teacher doesn't allow them to discuss among themselves the solution of the physics problem: “Every time, I try to ask a colleague about a certain point to comprehend the physics problem, the teacher prevents us from discussing with each other”.

On the other hand, one of the first-year students (S1F) clarified the importance of the teacher’s relationship with his students and that this reflected positively on their thinking in solving mechanics problems:

> The teacher’s relationship with students should be a relationship with no admonition or student embarrassment; it should include cooperation from the teacher’s side to make space for thinking in solving mechanics problems.

Another student from the first-year (S8F) agreed with S1F about the importance of the teachers’ friendly relationship with students to support students’ thinking:

> Teachers’ dealing with their students in some cases limits the thinking level of students, because teachers who deal with us in a friendly, affectionate way makes us think and give us a wide horizon for thinking and interaction in physics lectures when they explain physics problems on the board, and therefore reducing the load of information on our mind.

However, one of the teachers (T5P) considered that his relationship with his students was good, and that he has had to practise “firmness and strictness, fearing that some students may slight the teacher”.

The above evidence from students and teachers of both years emphasised that the interaction between the teacher and his students and between students themselves is almost non-existent, except one of the first-year students who clearly described enjoying participating with his teacher. Also, the above quotes underline that the teacher's dealings with his students should be based on respect and the building of a friendly relationship in order to give students the opportunity for thinking and interacting during physics lectures.

6.5.2 Physics teaching methods in the university

All students and teachers from both years clearly spoke from different perspectives about the importance and the role of teaching methods that should be used to help students understand and deal with physics problems in general and mechanics problems in particular. Furthermore, the findings suggest that all participants expressed a set of concerns about the teaching methods used in the explanation of physics problems. These concerns are related to the absence of diversity in teaching methods, how teaching methods affect students' understanding and their thinking, and how certain teaching methods encourage students to rely on memorisation. Also, teachers from both years gave reasons why they did not use varied methods in teaching physics problems. The most important results that appeared through analysing both the interviews and classroom observations will be presented. For instance, a first-year student (S3F) believed that diversity in terms of methods in teaching physics would encourage them to learn to solve problems in physics, and he gave an example of teaching methods like cooperative learning:

> There is no diversity in the teaching methods in physics lectures. Meaning that if there is excitement or co-operative learning or the teacher makes the class active in a way that attracts the students to the scientific material, the student will, as a result, understand the method of solving.

In addition to that, a first-year student (S6F) mentioned that the teaching method used by the teacher influenced his understanding: "when the teacher explains, I do not get what he is saying. I find him moving to a new idea or step with no link or preparation, so I get lost, and my mind becomes overloaded cognitively". One of the first-year students (S5F) saw that the teaching method used by the teacher obliges the students to memorise instead of think:

> The teaching method has a vital role in influencing our thinking and our understanding of mechanics because I notice that most of what has been taught to us is memorization and the teacher is the one who forces us on this method. This suggests that the teacher solves Newton laws and applies them on a problem, after that he tells us that in the exam there will be a problem like the one, he explained to us, so memorize the problem to be able to solve in the exam.

One classroom observation (O5F) confirmed what a first-year students (S5F) said, that the teaching methods used by the teacher influenced students' thinking because, during their explanations, teachers encouraged students to memorise. Based on the observation, it seems that the teacher wanted to teach physics using rote memorisation. For example, it was observed that the teacher repeated the term "memorise" five times in the lecture and focused on certain laws, definitions and exercises that would be among the examination questions. Also, in another observation (O6P) and in the same context, the teacher told the students directly:

> This exercise will be in the exam. Do you want to succeed or not, guys? I'm not a charity to distribute grades to you. You have a forty-page booklet, you need to memorise it well [...] the summarised booklet I have mentioned to you will be in the exam.

A preparatory-year student (S2P) said: "this will make us accustomed to memorise rather than thinking". On the other hand, a first-year student (S4F) stressed the importance of the way of a teacher's explanation on students' thinking and understanding: "if the teacher makes me like physics with his way of explaining, this motivates me to think and understand, but in fact, most teachers use traditional methods such as lecturing when delivering the information to the students". Also, a first-year student (S3F) expressed the view that the teaching methods in the university are supposed to focus on problem-solving skills in order to teach students how to think and solve physics problems:

> Teaching methods at university should be focused on problem-solving skills and to teach those skills and thinking skills generally to the students, because it gives us the ability to think well when dealing with physics problems.

In addition to this, one of the first-year students (S10F) indicated that the teachers do not connect what is taught with reality although this is the best method to understand physics problems:

> Relate to reality and deliver the information in a way the student could understand physics problems not memorise them and write them in the exam. This means that delivering the information to the student should be through reality stimulation; the whole universe is based on physics!

This was confirmed through teachers' interviews. For instance, a preparatory-year teacher (T5P) agreed with S10F about the importance of connecting the mechanics problems with reality: “mechanics problems may be easy for the student if they are linked to his reality”. Also, a first-year teacher (T6F) was critical of the way teachers deal with physics problems that include mathematical aspects; they deal with them “as if they were separate mathematics problems, not related to physics, which means that there is no practical application in the daily lives”. During classroom observations, it was noticed in four class visits (O1F, O4F, O5F, O8P) that the teachers linked the mechanics problems to daily reality, while in six visits (O2F, O3F, O6P, O7P, O10P, O9P) no link was noticed.

One of the results that appeared from students’ interviews regarding the aspect of teaching methods is the use of visual presentation tools. A first-year student (S7F) talked about his teacher in relation to his explanation during mechanics lectures and suggested that the teacher should use technology during the teaching to facilitate the difficulties of physics problems:

The teacher is supposed to innovate in his explanation and explain the lecture to us when explaining mechanics using the tools of visual presentation to make it easy for us to understand physics problems.

Then the same student referred, in another part of the interview, to the idea that the teacher should explain to students how to think and solve mechanics problems:

> Clarify to the student how the mechanics problems are being solved in physics, and that is by applying the steps of solving step by step and linking them with the physics problem [...] The problem is that the teachers don't teach us how to think when dealing with the solution of mechanics problems but explain them on the board to themselves.

Also, one of the first-year students (S19F) confirmed that the teacher should care about his teaching in terms of organising the board and involving students with him during his explanation, because that would be reflected positively in clarifying the solution to physics problems:

> If the teacher organizes the board in a certain way or involves the students in the solution in a way that shows them how to plan in solving any mechanics problem, that would facilitate the solution for us.

In the same vein, a first-year student (S8F) indicated that the diversity in teaching methods reflects positively on the student’s thinking and his focus during explanations:

> I wish that the teaching wasn't so dry in terms of physics laws and solving physics problems. The teacher should change his teaching method, which means that it shouldn't be just dictation, but he should use other methods such as using brain storming or starting the lecture with a technique that contains some sort of attention-grabbing so that the student comes back even more active and can think and focus with the teacher during explanation.

One of the preparatory-year students (S12P) described the teacher's explanation in the physics lecture; he seemed unhappy about his teaching and was facing difficulties to follow the teacher due to the fast explanation: "[the lesson is] lecturing only, even if he explains, he explains quickly [...] subsequently I cannot follow him during solving physics problems".

Based on all eleven classroom observations, I did not notice that teachers gave their students the opportunity to practise and implement the steps of problem-solving. For example, in one classroom observation (O10P), it was noticed that no practical aspect of the mechanics problems was presented in a way that would allow the students to apply this method and attempt to solve other mechanics problems. Instead, the teacher solved the problems due to time constraints. Moreover, during the lecture, the teacher said to the students: "Excuse me, I'm going to explain fast because we have eight mechanics problems and a limited time. So, if I explain to you every problem of the syllabus, we won't cover all the syllabus". Also, in another classroom observation (O9P), the teacher stated more than once: "answer fast, we have no time".

The preparatory-year students (S12P) also mentioned a further point in relation to the way of the teacher's explanation of physics problems, and mentioned that the teacher was using Power Point in an ineffective manner during his explanation:

> [it is] written on PowerPoint slides with its solution and [the teacher] shows it to us as if it's a reading material. He doesn't use the board and the pen in explaining this problem, but he is satisfied with reading the problem and how to find the solution only in a readable manner.

Furthermore, one preparatory-year student (S17P) was critical of the teacher who "doesn't know how to deliver the information to the student and he doesn't know how to get on the level of the student".

From the teachers' perspective, a first-year teacher (T6F) believed that because of the lack of time he could only solve one physics problem with the students and then ask them to solve other problems following the same model without given them a variety of physics problems. However, this teacher was critical of other teachers about their teaching:

> I solve a physics problem on the board and after that, I ask students to solve another problem in the same way because we do not have enough time [...] Some teachers make an effort but cannot deliver the information to the student.

Meanwhile, a first-year teacher (T7F) clearly stated that he could not use a variety of teaching methods in his explanations and, instead, put his emphasis on getting physics information into the students' minds because of his concerns regarding the limited time and the length of the syllabus:

> Diversifying teaching methods is difficult for me because of the limited time of the lecture and the required explanation must be done and we are also required to finish the syllabus. We are also demanded to insert a huge amount of information in the students' minds.

As indicated by a first-year teacher (T7F) regarding the relationship between the aspect of time and the methods employed in teaching physics, a preparatory-year teacher (T2P) mentioned that the physics syllabus in the preparatory-year "is very lengthy and as a result I couldn't provide the opportunity for discussing and co-operative learning in the lecture so as to not waste the time of the lecture". Also, a first-year teacher (T10F) mentioned that he faced time constraints, and, for this reason, he had to explain the syllabus quickly in order to finish it on the time. This, therefore, had an impact on students' understanding: "I should teach my students in the time given and thus, the syllabus is being explained quickly at the expense of students' understanding and thinking". Also, a preparatory-year teacher (T5P) agreed with T10F that he explained some parts of physics problems quickly due to time constraints and because he assumed students should have studied these problems in previous years.

When conducting one classroom observation (O9P), it was noticed that there was no practical aspect to mechanics problems whereby the student could apply and try solving other mechanics problems. Instead, the teacher solved them on his own due to the limited time available. The teacher said during the lecture: "excuse me, I'm going to explain quickly because we have eight mechanics problems and limited time. If I explain every problem in the booklets to you, we won't finish the syllabus".

A preparatory-year teacher (T9P) indicated that the teacher had expertise but might not excel in delivering the material to his students: "his method of delivering information is very weak or puts the students off, so the teaching methods can attract or put students off from understanding physics problems."

When asking the teachers during the interviews whether they had attended training courses or workshops concerning teaching of thinking skills like problem-solving, more than half of the participating teachers (T2P, T3P, T6F, T7F, T9P, T10F) indicated that they had never attended training courses or workshops related to this aspect, due to time constraints or not being invited. Four of the teachers (T1F, T4F, T5P, T8P) had attended training courses and workshops on teaching methods.

Also, through classroom observations, a number of issues appeared, the most prominent of which related to the fact that the teacher did not provide students with the opportunity to participate in solving mechanics problem. If the questions were asked by the teacher, he did not provide opportunities for thinking (O1F). In another observation (O3F), it was noticed that the teacher explained quickly and there was no order in his explanation of mechanics problems on the board, so he explained the mechanics problem and wrote all over the board.

6.5.3 Physics teaching methods in schools

In this section also, the results showed how the teaching methods used with the students while studying physics in secondary school had influenced the preparatory-year and first-year students in becoming accustomed to memorisation instead of thinking. Also, some teachers, through their teaching methods, did not care to develop their students' thinking and problem-solving skills. A first-year student (S10F), for example, was critical of the way his teacher in secondary school encouraged students to memorise:

Our teacher in secondary school, his teaching methods in physics were bad, and he was entering the class and explaining the material but [...] he accustomed us to memorisation rather than challenging our ability to solve difficult physics problems.

On the contrary, a first-year student (S6F) disagreed with S10F about the teaching methods of his teachers, as his teacher in secondary school influenced his choice of the physics speciality through his teaching method and "made [them] try and experiment until we understood".

> As mentioned by one of the preparatory-year students, the teacher during his explanation of the physics syllabus in secondary school was "omitting some points and gave us summaries and, I think, this affected our understanding of physics problems because I felt that I had not gained a solid background from secondary school" (S20P).

This was confirmed through interviews with the teachers. For example, a preparatory-year teacher (T3P), who clarified that his children were studying in secondary school in the KSA and that he found that their teachers were omitting several parts of the physics syllabus:

> Curricula are good, and development is good, but the problem is in the explanation and practical application. The teachers don't teach the whole syllabus and points that challenge thinking. There are teachers who omit some parts of the syllabus from lessons delivered to students.

In the same context, one of the preparatory-year teachers (T9P) indicated that, when students come to university from schools, he was surprised that "the student has not studied some lessons in physics". The teacher explained the cause for this as "specifying specific parts of the syllabus, because the teachers were omitting or condensing certain points, so, I get surprised when the student asks me to condense physics lessons in the university".

Also, participants talked about their experiences in the classroom with regards to teaching thinking skills and problem-solving in physics. A first-year student (S8F) mentioned that he had not acquired solid basic knowledge in secondary school in terms of thinking skills and problem-solving because teachers did not focus on these skills:

> The explanation of the teacher in secondary schools were sometimes not focusing on these skills or did not understand how to apply them, for instance, steps of problem-solving when dealing with physics problems.

A preparatory-year student (S12P) agreed with S8F about the fact that teachers did not focus on thinking skills in physics lessons in schools, although the physics curriculum contains many skills that encourage students to think:

> The physics syllabus includes thinking skills, but the problem is that the teachers don't give it much attention in schools. There are some exercises which call for thinking, but the teacher ignores them, and this will reflect

> negatively on students' thinking when they deal with physics problems at the university.

Another result that emerged from analysing the preparatory-year students' interviews was that two participants indicated that thinking skills had been included in the physics curriculum in secondary school, but they did not benefit from it. It was one of the issues most highlighted by the participants. For example, a preparatory-year student (S18P) declared: "the books that include thinking skills in physics in the maths and science development project were marginal, and we had no interest in it and even the teachers didn't focus on it and use them during the teaching". Moreover, a preparatory-year student (S13P) indicated that students' concerns are focused on passing exams in secondary school rather than focusing on thinking skills: "we didn't focus much on it because our teachers made us to focus on the scientific material and succeeding in exams". Also, four first-year students (S3F, S5F, S6F, S19F) agreed with S18P and S13P about the teachers not concentrating on thinking skills in secondary school and the concentration was on how to get high marks in the final examination.

Furthermore, a preparatory-year teacher (T5P) believed that the didactic style of teaching had an impact on the students' thinking:

> Lecturing was the main focus, meaning that it was a memorization process. Focus on the memorization process in the years before university negatively reflects on our students in university. Meaning that teaching methods, unfortunately, in schools, do not accustom students to reaching their own conclusions, thinking and solving problems; these skills do not exist in the student's mind, and are almost non-existent. These are essential for subjects like solving physics problems.

The above two sections have highlighted the importance of teaching methods as one of the most significant aspects affecting students' understanding of physics problems, from the students' own perspective. Also, the findings of both years from students mentioned that current teaching methods in physics lectures do not encourage students to understand or think. Moreover, the findings from the teachers from both years revealed that teachers do not use the steps of problem-solving in their teaching. In addition, some teachers did not use creative teaching methods; rather, the traditional didactic style of teaching was used, because a long syllabus had to be fitted into a short teaching time.

The aspect of interaction and teaching methods, and their impact on problem-solving in physics will be discussed in more detail later, in the Discussion Chapter. In the next section, the findings relating to the fifth theme will be presented: *institutional factors affecting students' learning of problem-solving in physics.*

6.6 Institutional factors affecting students' learning of problem-solving in physics

This section focuses on the main factors that impact on students' learning of problem-solving in physics. These factors emerged through the interviews and the classroom observations with preparatory-year students and their teachers and first-year students and their teachers. The acknowledgement of these factors may reflect positively or negatively on dealing with the steps of solving mechanics problems in physics. In this section, the factors that emerged are: (1) classroom environment, (2) lack of suitable facilities, (3) university management and physics department, and (4) syllabus issues, as Figure 6.8.

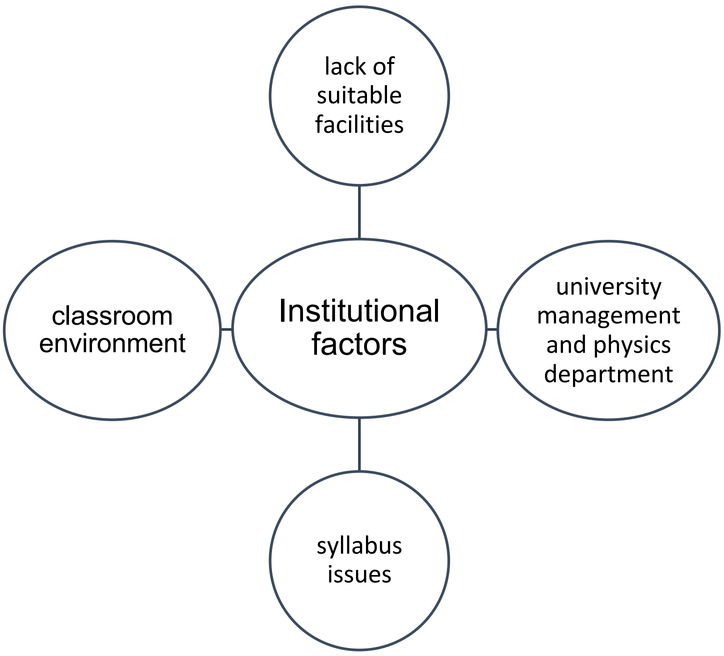

Figure 6.8: Institutional factors

6.6.1 Classroom environment

The current study aimed to investigate the factors that affect students' learning of problem-solving in physics. Among the factors that appeared from the analysis of students' and teachers' interviews were their complaints about large class sizes. This issue was believed to prevent students from participating during physics lectures or teachers from being creative during their explanations in the lectures. Two first-year students and two preparatory-year students agreed on this point. For example, a preparatory-year student (S12P) mentioned:

> In the physics classroom, there are about 60 students, because it's a preparatory-year and the numbers are huge, so sometimes the teacher's voice doesn't reach us clearly and therefore, it is difficult to understand physics problems.

A first-year student (S6F) agreed with S12P regarding the large number of students in the class: "the more the number of the students in class increases, the more it is difficult to participate or to get assistance from our teacher".

As for the teachers, a first-year teacher (T4F) mentioned:

> The thing that bothers me is the large number of almost 46 physics students in my class. I was previously teaching around 25 students, so I could innovate with them in teaching methods and in thinking when solving physics problems.

Another first-year teacher (T6F) spoke frankly about the excess in student numbers inside the class and how this issue prevented him from giving his students a variety of physics problems. He also added that this prevented him from guiding students' thinking during solving physics problems:

> When I teach 15 students or 20, I can know them by name, and I can follow their thinking. But when I teach 60 or 70 students, to be honest with you, I solve one physics problem on the board, after that, I give them another one of the same style because I cannot follow them and guide their thinking.

A preparatory-year teacher (T2P) confirmed the previously stated views of teachers of the first-year:

> Honestly, I face a big problem with the number of students in class in a way that makes me unable to follow what problem the students face while solving mechanics problems or physics problems in general.

This was confirmed by other preparatory-year teachers (T3P, T8P, T9P) who emphasised that the number of students in the classes prevented them from guiding students and assisting them in solving physics problems.

Concerning the provision of a quiet class environment, during class observations (O1F, O7P, O9P), loud student voices could be heard inside and outside or near the classroom, which may impact the students' ability to hear the teacher's voice, affecting the focus of the students inside the physics class. Two of the participants mentioned that it was the teacher's role to preserve the class environment and this was an important element to provide a suitable class environment for the sake of understanding the physics lessons. For instance, a first-year student (S3F) indicated:

> There is a group of students who sometimes talk to each other inside the class without caring about the explanation; this causes us confusion in class and prevents our understanding and the teacher may stop his explanation to be able to control the class [....]. All these things happen because of the teacher's negligence inside the class, because the teacher should be firm in class management.

A preparatory-year student (S17P) explained the situation of the students during the physics lecture and complained about their behaviour towards a physics teacher. He claimed that some students wasted time during physics, which affected the teacher's performance and eventually the students' understanding also:

> Some students try to disturb the teacher, whether through being late to the lecture or through questions, seeking to create arguments with the teacher and wasting physics lecture time. As a result, the teacher gets angry. Eventually this influences the teacher's explanation in a way that makes the teacher explain fast and so this influences our understanding. So, the teacher should work on providing a suitable class environment for the sake of understanding the scientific material.

In line with the opinions of the participants on the matter of class management, during classroom observations (O1F, O4F, O7P) the repeated late entry of students was noticed, in the beginning, the middle and at the end of the physics lecture, which caused the teacher to stop explaining several times. I found that the teacher did not seem to care about the late arrival of the students so, as a result, the students came whenever they wanted. I also noticed in a physics lecture (O10P) that a student made a phone call for two minutes during the teacher's explanation and also three students sitting beside me were using their phones to watch matches or games on YouTube videos.

To summarise the above findings, the data highlight the participants' concerns about the large class sizes in physics, which affects the classroom environment and impacts negatively on students and teachers. This, in turn, did not support or encourage students' thinking in solving physics problems. The next section presents another factor, which is the lack of suitable facilities.

6.6.2 Lack of suitable facilities

The lack of suitable facilities at the university could be an important factor limiting students' learning of problem-solving in physics and the development of their thinking skills. During the interviews, a number of students advocated the provision of a suitable environment and the creation of specific places where students could sit together and discuss what they did not understand in physics lectures. For instance, a first-year student (S10F) expressed the following view:

> Suitable facilities should be provided for students. For example, we need specific places like group discussion rooms [....]. I find the students in the university campus smoking or in the corridors, what makes them do that? Because they cannot find a place to sit or even meet for a discussion about what they do not understand in physics lectures.

A first-year student (S5F) also talked about the absence of suitable instructional tools to facilitate understanding physics:

> The physics classes are not prepared for the students, nor is the technology or suitable instructional tools in order to facilitate understanding physics; the projectors here only work once a year.

Further pointing to the issue of arriving at classrooms, when distributing my questionnaires to the students, the students, their teacher and I were surprised that the door of the classroom required fingerprint verification and we couldn't enter, forcing us to spend about fifteen minutes of lecture time searching for another available classroom. This is because the physics department informed the teacher that the physics class had been moved to another classroom which required fingerprint verification; the teacher did not know about that fingerprint verification. Providing suitable facilities in order to make it easy for teachers and students to enter classrooms is an important element to take advantage of the lecture time and give the teachers enough time to explain the lecture properly rather than explaining it fast and wasting time to find another available classroom. This might give students sufficient time to ask questions and understand physics problems.

A first-year student (S4F) wondered how they could be asked to think while the classrooms were not prepared:

As physics students, how can we be asked to think and learn or interact with others to understand physics problems while some classrooms are in a tragic state and ruined, in a way that some of the chairs and the boards aren't in a good shape?

The following Figures are examples of pictures taken during classroom observations in both years in order to show the reader the state of the facilities in the Department of Physics. Also, it shows the students' lack of respect for their environment in the university.

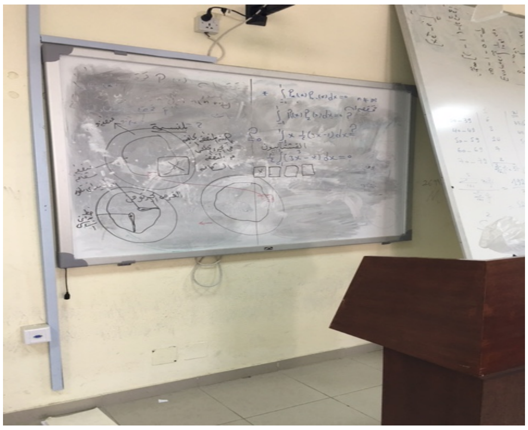

Figure 6.9: Whiteboard in an observed lesson

Figure 6.10: A first-year classroom

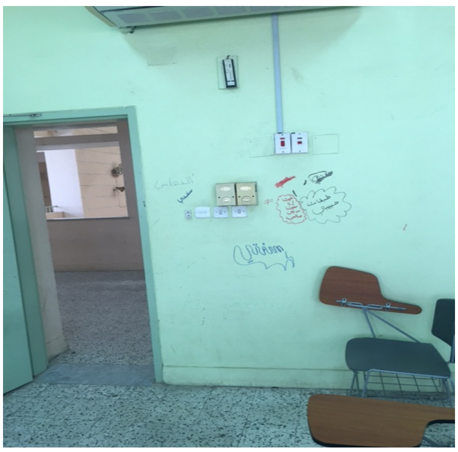

Figure 6.11: A preparatory-year classroom

Also, a preparatory-year student (S20P) clarified that if the classroom was prepared, this would have been reflected in their understanding in physics problems as this could aid cooperative learning:

> In most of the classrooms, the chairs are immovable, fixed to the ground. So, if the physics classroom was prepared for us in a way that, for example, could create an atmosphere of cooperative learning, the situation would have been better even in our thinking to understand physics problems.

In a similar respect, in terms of providing a suitable environment, a first-year student (S21F) emphasised the issue of providing a suitable environment and stated: “If we, as physics students, do not find a suitable educational environment and the assistance that helps us overcome the problems they face, this will kill creativity”. Moreover, one of the first-year students (S6F) spoke about providing a library suitable to his needs in relation to understanding physics problems: “When I don't understand a certain part of the solution of a physic problem, I search for it on websites because there is no suitable library that meets my needs”. In addition, a first-year student (S10F) discussed another point related to the lack of available tools in the physics laboratory and argued that this affected their understanding:

> Scientific equipment is a problem, as there is a lack of equipment for the teacher to perform practical experiments. One time, there was no place to do physics experiments except in the chemistry laboratory and the equipment there had nothing to do with physics. Does this attract student to the physics lessons? Definitely not. Or does this make us understand physics?

With respect to laboratories, a first-year student (S7F) wished that laboratories were provided for some lessons:

> I wish that physics laboratories were provided for some lessons because lectures are not applied practically in the laboratory, and we need to understand these physics lessons. The university didn't provide laboratories. Additionally, some laboratory devices do not work, to an extent that we have to work in one laboratory. Therefore, this influences our understanding of physics problems.

The results also confirmed another issue related to the suitability of facilities, namely car parking. A first-year student (S10F) mentioned how the issue of parking delays their attendance on time in physics lectures and makes him not care about his studies in physics:

> Due to the lack of suitable facilities, such as, for example, the problems of

parking; because I spend much time every morning to find parking because the university has limited space for parking. So, we park on the pavement, and at the end of the day, we get fined by the traffic warden, and therefore, all these stressful things cause me not to care about my learning or thinking in physics and delay my attendance on time in physics lectures. But I just want to graduate from the university in any way.

As for the teachers, concerning the lack of suitable facilities, it was interesting to note that only one preparatory-year teacher (T5P) referred to this point whereas the rest of the teachers did not mention this issue at all:

> Suitable means for learning should be found and provided, as with suitable teaching means [...] Also, the nature of classrooms doesn't allow us to create an environment to make the students discuss the solutions of physics problems or develop their thinking because the classroom chairs are fixed and immovable.

The above quotes highlighted the importance of providing suitable facilities whether at the level of the physics classrooms and laboratories or the car park. Participants explained how all these facilities would support their understanding in physics.

The following section shows another set of factors emerging from the study, which is the university management and Physics Department.

6.6.3 University management and physics department

Two first-year teachers and a preparatory-year teacher pointed out that the administration of the university plays a role in influencing students' thinking and learning. For instance, a first-year teacher (T10F) saw the importance of the university management in terms of catering for teachers' needs, with its impact on students' learning:

> If the management is successful in a way that provides the physics teachers with what they need, such as workshops or training courses about thinking skills, problem-solving skills and teaching methods, this would positively reflect on students' understanding in physics.

During interviews, three of the teachers (T1F, T6F, T2P) referred to the role of the university management and the Physics Department and its influence on the teachers, which reflects on the students. For instance, a first-year teacher (T1F) declared:

> The most important factor which motivates the person to teach is to feel that [...] the administration of the department and the university appreciate my efforts [....]. For example, in some cases, the Physics Department administration doesn't find anyone to teach a certain course; as a result,

> the department asks me to teach this course that is considered distant from my specialty because they cannot find anyone else to teach it. So, in that way I will be forced to teach the course, and this will be difficult to me and for my students as well, but if I teach a course I desire, and the administration provides for my needs, I will feel that I'm doing my job better and this will certainly be reflected, one way or another, in students' learning and thinking.

In another part of the interview, the same teacher (T1F) complained about the situation in the Physics Department which accepted students with poor academic levels in physics. He believed that this situation affected the teachers' performance. This teacher added that the university management should select the students, arguing:

> When the university management brings me students with a poor academic level, I try to explain this to them several times. When this occurs, I become bored and eventually I have to make the student pass regardless of his understanding in physics, but I do not know what I can do for him. So, we have students in the department for about eight or nine years, those students take the course with me more than once, what can I do for them? If the student is at that level, then who allowed him to join the Physics Department? Certainly not me! So those responsible for that are the administration that allows him to repeat the syllabus, giving him the freedom to act as he pleases. Who allows him to do this, me? Of course not! So, the university management and the educational institution should know that the physics teachers are not machines that you input anything into and ask for a good output.

Also, a preparatory-year teacher (T5P) stressed the importance of moral and material support for faculty members from the management of the department and the university, to assist their performance in their lectures.

The above quotes show how two teachers from both years emphasised the role of the university management and the Physics Department to support students and teachers in teaching and learning. This support, according to these participants, would be reflected in students' thinking in physics. Also, one participant emphasised the role of the Physics Department in the selection of students with an adequate academic level in physics.

Another issue to be considered here is related to the influence of the university management on the nature of tests in the university. For example, six of the participating teachers (three first-year and three preparatory-year) felt that tests with multiple choice questions indirectly affected students' learning of problem-solving in physics and their way of dealing with problem-solving. According to them, these kinds of test questions are problematic and do not support students' thinking; they want the university management to take their voices into account about the design of the tests because they are not satisfied with this kind of testing and they are not allowed to design the test. For instance, a first-year teacher (T1F) expressed this view:

> The university policy is to design the test based on multiple choices, so we cannot do anything to change it, but I'm not satisfied with this kind of testing as it has damaged the skill of expression and problem-solving. Also, I find that some students may choose the answer randomly without any thinking, so how can I evaluate a student's skills in problem-solving? I think multiple choices tests make students memorise.

Also, in the same context, T10F expressed his views regarding this type of testing:

> Multiple choice testing is a method that makes the student accustomed to memorisation instead of understanding and thinking of the solution of the mechanics problems; I am not happy about it, because there is a testing committee responsible for making tests at the end of the academic year and we do not have any choice to change this kind of test.

Moreover, the findings clarified that a wide range of students ignored solving physics problems in the tests. This was confirmed by other teachers (T8P, T5P, T4F); for example, a preparatory-year teacher (T8P) mentioned a specific point:

> The test is divided into two parts, the first part, consisting of 70% of the grade is multiple choice and the other part, about 30%, is a collection of different physics problems. 90% of the students leave the second part unsolved, and the university management plays a role in this, but we hope them to hear from us in order to reduce the percentage of multiple choice.

Here, one of the preparatory-year teachers (T3P) expressed his experience of conducting his own assessment in the classroom. (Teachers are responsible to conduct their own assessments in the classroom but, in the final examination, the tests are prepared by a testing committee.) He indicated that it is difficult to challenge students' thinking, because of the officials of the university:

> We, at the university, face some difficulties when we try to challenge students' thinking in physics problems in the test. There are those who disagree with us among the students and the officials in the university who ask us: why is the failure rate so high? Therefore, we try to make the exam easy to avoid failure.

Based on the above, the teachers from both years emphasised the role of the university management and the Physics Department and its influence on the teachers, which reflects on the students. Also, they seemed unsatisfied about the style of the test questions at university and claimed that they encourage students to memorise rather than think to solve physics problems.

The following section presents the results related to the syllabus which is taught in preparatory-year and first-year and its relationship with students' understanding of problem-solving in physics.

6.6.4 Syllabus issues

In this section, the perspectives of students and teachers in both years are presented with respect to how problems mentioned in the mechanics syllabus play a role in understanding physics. Another point discussed is how the thinking and learning skills in the preparatory-year syllabus play a role in helping the students in aspects of thinking when solving physics problems. Thus, in this section, the findings from all participants from both years will be presented in two ways: (1) physics syllabus, and (2) thinking and learning skills syllabus.

6.6.4.1 Physics syllabus

Through interviews with students and teachers, all the participants in the preparatory- and first-year referred to the physics syllabus from different perspectives concerning the solving of physics problems. These views relate to the physics syllabus and the reasons why students rely on summarised booklets instead of using a physics book. Before reporting the findings related to the physics syllabus, it is worth bearing in mind that in Saudi Arabia it is common for teachers to summarise their courses into short booklets and make it available for students. The following quote represents one of the views expressed by a preparatory-year student (S17P) who was critical of the physics syllabus and compared it to what he had studied at secondary school:

> The syllabus we study is a summarised booklet for the student. But the problem is that this booklet doesn't contain images to enable us to understand the physics problems well. While in secondary education, the books contain number of images that help us understand.

Another preparatory-year student (S2P) felt that the summarised booklet they studied “needs more clarity concerning the solving of mechanics problems”. A first-year student (S8F) agreed with S2P about the ambiguity of the summarised booklets they studied, and he believed that they were difficult for students.

Although the booklets which are studied in each year differ in relation to the content, he described his perspective as follows:

> The summarised booklet is unclear so, sometimes, the teacher expects that the explanation inside the summarised booklet is understandable to students and that it helps us in the solution of mechanics problems, or the idea is clear. So, from my point of view, I see that its level is higher than the students'.

Another factor influencing students not to use thinking in solving physics problems was given by preparatory-year teacher T5P. He emphasised the lack of coherence between the different parts of the booklet:

> In my opinion, I found that there is incoherence between sections of the syllabus as they are not linked with the previous parts because the material is collected from more than one book. There is a gap that makes the student memorize instead of using thinking in solving physics problems like analysing and concluding.

Also, one of the preparatory-year teachers (T3P) acknowledged that the summarised booklets are not beneficial for students to become familiar with a variety of physics problems, although these booklets are used:

> In the preparatory-year, summarised booklets are used and soon they will be in the form of a book, and these booklets are too summarized. They may not help the student much in getting accustomed to various physics problems.

A first-year teacher (T6F) was critical of the preparatory-year physics syllabus and he indicated that "unfortunately, physics material isn't formed as a book, and is a lost reference for the preparatory-year student".

A first-year teacher (T10F) was also critical about the current situation in the Physics Department in relation to the summarised booklets and how these booklets might affect students' thinking, because these booklets contain typos:

> The person who writes these summarised booklets may make typos, which influences students' understanding and comprehension in solving the physics problems.

However, six preparatory-year students (S11P, S12P, S14P, S15P, S18P, S20P) preferred their teacher's PowerPoint presentations rather than referring to a book because, at the end of the lecture, their teachers give them the printed slides. At the end of the term, students end up with a booklet of these slides and eventually just study with it, and an example of this view was confirmed by a preparatory-year student (S20P):

> A teacher provides us with PowerPoint slides at the end of every lecture. I think this is better for the student and helps him to understand how to solve mechanics problems because it contains colours and paintings, so I prefer it, but the book contains too many topics or makes you become lost.

In addition, a preparatory-year teacher (T2P) clearly said that he gives his students “the slides shown in the lecture, then the student prints them and studies from them instead of the book”.

The data indicate that the first-year students expressed their views about the physics syllabus which was reflected in their understanding. These views related to the content of the physics syllabus. Students shared a common belief that the physics syllabus was difficult. A first-year student (S19F), for example, clearly indicated: “I have a feeling that I will never understand and that's because the mechanics syllabus is difficult. So, even if I don't understand, I don't ask the teacher”. Furthermore, S4F added more explanation about why this syllabus was difficult: “I think that the mechanics syllabus is difficult because it's a new syllabus and requires deep thinking”.

Also, S1F for instance, described his feelings when the teacher explained a mechanics problem on the board:

> When the teacher explains a mechanics problem from the mechanics syllabus, I find it difficult from the first sight and this frustrates me. Then, I stop following him and my thoughts wander because of the problem’s difficulty and because the syllabus is too long, and it consists of more than one step.

One of the issues raised that appeared through the interview analysis of first-year students is that all the students referred to their dependence on summarised booklets rather than a book. They mentioned a number of reasons for this. One of these reasons, as mentioned by S3F, was the difficulty of the language of the book and its high price, which made him use the summarised booklet instead:

> Of course, if we go back to the book, we might be unable to understand the physics problems mentioned in it. As the language used in it is difficult and the book costs a lot while the summarised booklets are understandable, cheaper and smaller.

On the other hand, S6F mentioned that the teacher discouraged the students from referring to the book:

> The teacher is satisfied with us writing notes during the lecture and tells us to study only what has been explained on the board without referring to

> the book or that there are summarized booklets available even if they are incomplete.

The same student indicated in another part of the interview that the absence of a reference in physics affected his understanding negatively:

> To solve a problem in mechanics, you find that the information in the mind needs to be ordered and linked to avoid confusion. The reason for this may be the absence of a main reference in physics.

A first-year student (S5F) believed that the university plays a role in students not having a physics book and he blamed the university for this:

> The problem is that, in fact, on the day I joined university if they had made me commit to buying the book, I would have been accustomed to this. But when I joined university, I found a summarised booklet with a limited number of physics problems, while with the book you may get lost in understanding the solution, so why would we refer to the book?

In the same context, a first-year student (S19F) provided a reason for not being able to refer to a physics book:

> The teacher brings the summarised booklet with him in the lecture, he explains from it, and afterwards we photocopy it. I don't remember him giving us a reference from the syllabus.
>
> Also, S5F confirmed that: “The teacher doesn't make us commit to the physics book”.

At the level of first-year teachers, for example T1F justified his usage of a summarised booklet with his students instead of the book, saying:

> I use a summarised booklet with my students, and it is like a collection of more than one chapter from the book; they have been photocopied then formed into a summarised booklet. And this is because the teachers who taught mechanics before me prepared ready booklets, so I was committed to booklets as I don't want to go against my fellow teachers.

Also, among the reasons not to refer to the book is the fact that the language of the book is English, as mentioned by a first-year student (S7F): “The book of mechanics is written in English and the teacher helps us in the translation but sometimes the language forms a barrier in understanding mechanics problems”. A first-year teacher (T4F) confirmed this: “the book of mechanics for them is written in English but I translated it into Arabic”.

Another reason for a first-year student (S8F) not relying on the book is the effort the student would have to exert to obtain the information, in addition to the financial cost:

> We don't refer to the physics book because it takes effort from us to search for a piece of information, in addition to the financial cost. Even if you used the book, you find that we don't benefit from it completely, only to a small extent, while the summarised booklet is beneficial.

This was confirmed by a first-year teacher (T7F):

> We collect chapters in a summarised booklet and these chapters have been taken from a main reference. Instead of the student buying the whole physics book we try to relieve him financially so that he only needs to buy the summarised booklet.

One of the first-year students (S21F) explained his two reasons for not referring to the physics book:

> I find the physics book isn't beneficial because the teacher only teaches us two or three chapters while you find the book contains eight chapters. So, I take the book and photocopy the required part. Subsequently, the rest of the book has no benefit. Also, it is difficult to understand the physics problems because of the language of the scientific material.

Another teacher (T8P) mentioned that one of the reasons students use the summarised booklets instead of the books is due to the fact that teachers make students accustomed to relying on the booklet:

> The students in preparatory-year get used not to bringing the books and this is because the teachers here photocopy parts of the book and put them in a summarised booklet form and the student is satisfied with this.

The above quotes from both years of students and teachers illustrate that students are satisfied with the summarised booklet in both years. However, some students and teachers (S17P, S2P, S8F, T3P, T6F, T10F) were critical about this booklet, as mentioned above. Moreover, students and teachers from both years clarified some reasons that encourage students to use the summarised booklet.

In the next section, a number of the students and teachers from both years talked about the thinking and learning skills syllabus and expressed their views about how this syllabus supports students to use these skills in solving physics problems.

6.6.4.2 Thinking and learning skills syllabus

All preparatory-year students and their teachers, five first-year students and one first-year teacher expressed their views on the syllabus of thinking and learning skills. Among these perspectives, agreements and disagreements about the importance of this course and its role in problem-solving can be found. For instance, a preparatory-year student S16P saw that this syllabus gave him a set of benefits, especially in showing him how to deal with physics problems: “it clarified to us how to solve problems in steps, how to understand the problem, solve it and evaluate it”. A first-year student (S8F) agreed with S16P about the importance of the thinking skills syllabus: “for dealing with solving problems, it gave me a perspective into figuring out solution steps concerning physics problems”.

On the contrary, a preparatory-year student (S15P) disagreed with S16P and S8F about the benefits of this syllabus and he believed that the subject of thinking and learning skills “is nonsense and a waste of time” while a preparatory-year student (S13P) mentioned clearly that the reason why this syllabus was not important for him because of his belief about this syllabus: “We didn't benefit from the subject of thinking and learning skills in our study in physics because it's something intangible”.

In the same regard, a preparatory-year student (S11P) was critical about this syllabus regarding the nature of its content and he stated: “the subject of thinking and learning is one of the best subjects [....] but honestly, I suffer from the arrangement and order of its book because it is incoherent, and its translation isn't good”. Meanwhile, a preparatory-year student (S12P) discussed the subject of thinking and learning skills in physics and he mentioned the importance of this syllabus and, at the same time, he was concerned about making it separate from the physics syllabus because he thought that there was a good opportunity to practice thinking skills in mechanics problems lectures. He was concerned about the time consumed if this syllabus was included within the physics syllabus:

> I think that the subject of thinking and learning skills is a good subject, but the problem is that it is taught as a separate subject. I mean that every scientific subject should be accompanied with a subject of thinking and learning skills, so we can apply what we study about thinking skills in physics. Or this subject can be merged with physics like in secondary school as it is the case with the project for mathematics and science

> development. This might be difficult because it may consume the time of the lecture at the expense of the scientific material or it could be part of the practical aspects of physics.

Regarding applying thinking skills in physics, two first-year students were critical about the lack of practice of thinking skills. For example, S6F discussed the subject of thinking and learning skills stating: “I didn't benefit from it [...] there is no practical aspect to thinking skills”. Moreover, S7F added: “I didn't benefit from it because it's not an important subject to my specialization”. Also, a first-year student (S4F) talked about his experience when he was studying thinking and learning skills in the preparatory-year, and concluded that infusing thinking skills within the physics syllabus might be beneficial for understanding and solving physics problems:

> We, in the preparatory-year, have studied a subject called *thinking and learning* in a more detailed way, so I find that we didn't benefit from it. So, if every subject of physics included how to solve, how to deal with solving mechanics problems and how to think, it will affect our understanding.

A first-year teacher (T7F) agreed with S12P’s and S4F’s idea that the subject of thinking and learning skills should be included in the physics syllabus:

> I think that it should be and remain part of the physics syllabus and it should be integrated within the course because it helps the student and directs him in using thinking skills like problem-solving, concluding and analysing, and this is in comprehending the scientific material, as its presence in the syllabus is considered to be like salt for food.

Confirming this, preparatory-year teachers (T3P, T5P, T8P) agreed with S12P and T7F about integrating this syllabus with physics. They mentioned that the subject of thinking and learning skills should be included in the physics syllabus in order to enhance students’ thinking in physics.

On the other hand, a preparatory-year teacher (T2P) believed that students would benefit from this syllabus if it was taught to them, but he was concerned about time; he stated:

> We teach the students some skills, how to think, but when there is a specific syllabus for this, the student will have enough time to comprehend these skills. [...] We in the Physics Department won’t have enough time to explain thinking skills while explaining the scientific material.

Moreover, a preparatory-year teacher (T5P) did not note any improvement in students’ thinking in relation to solving physics problems during his teaching:

“We didn't notice its effect on the students in their thinking and dealing with solving problems”.

The factors that appeared in this section seem to be important and require further discussion, as it will be shown in the Discussion Chapter. In the next section, the findings relating to the sixth theme will be presented: *sociocultural factors affecting students’ learning of problem-solving in physics.*

6.7 Socio-cultural factors affecting students’ learning of problem-solving in physics

This section sheds light on a number of social and cultural aspects that play a role in influencing students to learn problems solving in physics emerged through the interviews and the classroom observations with preparatory-year students and their teachers and first-year students and their teachers including: (1) society forcing the student to choose a speciality, (2) living conditions, (3) society’s role and its influence on students, and (4) language issues, as Figure 6.12 shows.

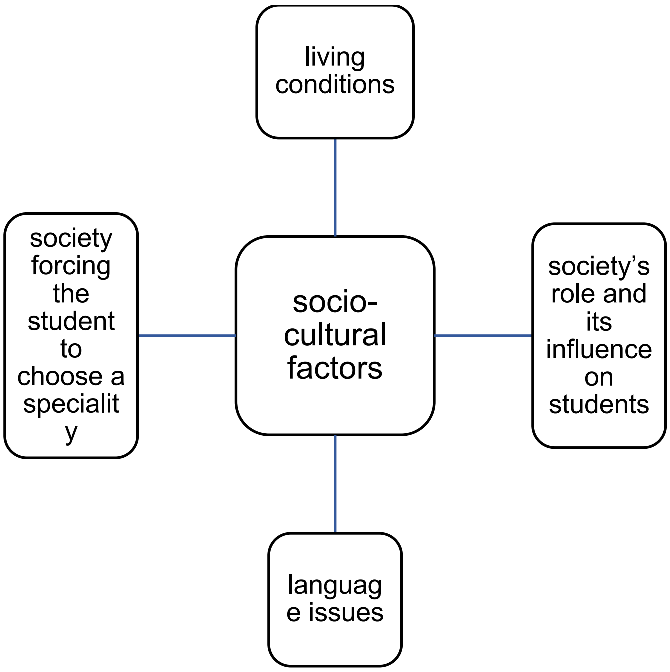

Figure 6.12: socio-cultural factors

6.7.1.1 Society forcing the student to choose a speciality

Through the analysis of interviews of first-year students and teachers from both years, seven students (S1F, S4F, S5F, S7F, S8F, S10F, S11F) and four teachers (T3P, T5P, T6F, T8F) expressed the view that students enrolled in physics without any love for the subject, but that society forced it on them. For example, one first-year student (S4F) confirmed this by saying:

> Some students are being forced to study physics by their families or their community. As a result, their presence in the classroom with us influences our understanding and disturbs the teacher many times during his explanations of physics problems and wastes his time […] because those students cannot understand very well.

Also, a first-year student (S5F) mentioned that his family played an essential role in his choice of specialty, indicating that it was not his desired area of specialisation:

> My desire was to study biology, but one of my brother's specialisms was biology, so my family insisted that I enrol in the specialism of physics. So, I study physics with no desire; that's the reason why I do not care to understand it well.

A first-year student (S10F) confirmed this issue of society forcing students to choose a speciality merely due to the importance of 'reputation' in the Saudi context.

> The student does not choose the speciality he desires, but the society forces it on him [and] the student chooses his speciality even if he doesn't have a desire for it because of the issue of reputation and position in Saudi society, regardless of his ability to understand physics problems.

Another first-year student (S1F) indicated that certain students enrol in the physics specialism due to society forcing them to choose this speciality, and he saw that this will affect them negatively in terms of their thinking and learning:

> Students want to join other colleges, such as the college of administrative and financial sciences and the college of arts, but their parents or family see these colleges as inferior and, therefore, these students are forced to study physics without conviction, and they do not want to learn or think.

Three first-year students (S7F, S8F and S11F) saw that society plays a role in students choosing scientific specialisations rather than humanities, because in the Saudi context, it is believed that choosing scientific specialisations enable students to get a job sooner. An example of this view was expressed by a first-year student (S8F):

> Students choose scientific specialisations rather than humanities and the social sciences at the expense of their desires because, in our culture, scientific specialisations are better than others for employment.

When teachers were asked at the end of the interviews if they wanted to add further comments, teachers from both years saw that forcing students to study what they do not like, impacts negatively on their studies in physics, as shown in the following example from first and preparatory year teachers' interviews: "students shouldn't be forced into a choice of specialism, because this might affect their ability to think, solve physics problems and understand them" (T6F). Similarly, one preparatory-year teacher (T3P) explained that the fact that students are forced to choose physics is reflected in their poor comprehension of the subject.

> Most students are forced into a choice of speciality. They are unfortunate and done an injustice. As a result, you can do nothing for them, and this is an ongoing problem and this problem affects students' understanding of solving physics problems.

In the same context, one preparatory-year teacher explained that the reason behind students' difficulties in understanding and solving physics problems is that half of students were forced by society to study physics:

> 50% of the physics students are victims of not choosing a suitable speciality because society forces it onto them, which is why I found students having difficulties to understand physics problems and solve them (T5P).

Likewise, one of the first-year teachers highlighted some factors which might affect students' thinking: "there are some physics students forced into a speciality by their families, their community or perhaps other factors, the influence of which is later reflected in student's thinking" (T8F). In this respect, two first-year students (S1F, S5F) mentioned that family and parents might affect students to study physics because they see the importance of employment after graduation and because their parents or families believe that choosing scientific specialities, such as physics, might help students find a job faster than choosing literary disciplines. Therefore, based on their opinions, they decided to study physics although they were not interested in studying this subject.

In addition to this, living conditions, as shown in the following section, are important among the social and cultural factors which play a role in influencing students to learn problem-solving in physics.

Through presenting the opinions of the first-year students and teachers of both years, this section reveals similarity in opinions among participants in that the students' choice of physics was not only due to their own desire but that there were factors that influenced them to choose this discipline, including family, society and reputation, which in turn has an impact on their understanding and thinking.

6.7.1.2 Living conditions

The data from five first-year students, two first-year teachers and three preparatory-year teachers indicated that living conditions have a role in influencing students to learn problem-solving in physics. These conditions are related to economic conditions, the matter of teachers' employment and family conditions; this was confirmed by other students and the teachers. For instance, a first-year teacher (T1F) referred to employment and believed this to be considered as one of the reasons which cause students not to be interested in understanding physics problems:

> With the current situation concerning the matter of teachers' employment, the students may wait several years after graduation until obtaining a job, and this might be one of the reasons that makes them not care about understanding or solving physics problems"

As a result of the current situation concerning the matter of teachers' employment, this teacher (T1F) asked himself "why should [a student] burden himself in thinking, as the future is uncertain for them?

Likewise, with respect to living conditions, one preparatory-year teacher (T9P) explained the situation of some students during physics lectures claiming that they are not eager to learn; he believed that they come to the university to get their monthly allowance rather out of eagerness to learn:

> I see that some physics students do not want to think and solve physics problems; they come to my lectures either for listening or sleeping, and I think they may attend university not for the sake of learning but to get their monthly allowance from the government; that's due to the living conditions of the student.

One of the first-year students (S21F) works outside university hours to earn a living due to his living conditions and he was explicit as to how these conditions affected his ability to solve physics problems:

> I work as an employee at night, so I don't have time to revise my physics

> lessons, let alone caring about my studying in physics, so I avoid dealing with complex and difficult physics problems, because I do not have time to think about them. I like to deal with simple physics problems which do not require deep thinking.

A first-year student (S8F) also explained the reasons which affected his understanding of physics problems due to his family situation:

> My occupation with work outside university hours for the sake of fulfilling my responsibilities towards my mother and father and to take care of them.

Also, he emphasised that family matters prevent him from attending physics lessons, as in this quote: “sometimes I cannot attend physics lectures due to family issues and this in fact affects my understanding of physics problems”.

The above quotations from students and teachers of both years showed that the economic and living conditions experienced by some students, as well as unemployment, made the students not care about their studies in physics and therefore, this might affect their ability to solve physics problems. Moreover, the study results also revealed, as shown in the following section, the role of society and its influence on the students’ learning in physics and, therefore, it can be argued that if the role of society impinges negatively on the learning of physics, this might affect students’ learning of problem-solving in physics.

6.7.1.3 Society’s role and influence on students

Seven students (S2P, S11P, S3F, S4F, S5F, S6F, S10F) out of 21 indicated that society plays a vital role in influencing their ability to solve physics problems. ‘Society’ was broadly described by these students using a set of characteristics which either refer to the family environment, the university environment, the school, or friends and colleagues. For example, a first-year student (S10F) explicitly referred to one aspect of the surrounding society, wealth and status, as affecting students’ understanding of physics problems and making them indifferent to understanding and enjoying physics, because they believed that the high position of their families can support them even if they do not get a job after graduation. The following quote is an example of this view:

> I know some students in my physics class, they come from rich families or their fathers have a high position somewhere; I see that they are indifferent to understanding physics problems and enjoying physics and their way of interacting with their teachers is bad, because they know that

> they will receive support and get money from their fathers or work in their father's business if they do not find a job after graduating.

Two first-year students (S3F and S4F) pointed to another component of society, namely, the university environment and friends, and expressed the view that these indirectly influenced their learning, especially when they face mathematical issues in physics problems. The following statement is an example of this view:

> Society has influenced our learning from our early years, so we are students that do not like mathematics, and this might be inherited from our surrounding community of friends and also from the schools and university community. So, while dealing with mechanics problems that contain equations and figures, we have a fear and a belief that we won't reach the solution correctly. This also acts as a barrier to understanding physics. (S3F)

Also, a preparatory-year student (S11P) seemed to construct his negative perception towards physics from his parents and colleagues before joining the university, and such perceptions shaped his mind to not be an active learner during physics lessons:

> When I was studying physics in secondary school, I had negative beliefs towards physics, because I heard from my parents and my colleagues in school that physics is difficult and that you need hard work. Physics has complex problems that need complex thinking, and therefore my mind is set on these negative terms, so now at university I find myself not ready to receive the physics information or engage in solving physics problems.

In the course of a discussion about the university community, one of the preparatory-year students (S2P) explained that if students are negligent, this will make their teachers not pay more attention to them during physics lessons which, in turn, negatively influences students' learning in physics:

> The university community in which we live has a clear impact on us as students. I have noticed that students with me at university are negligent and the teacher does not pay attention to us; this will affect our learning negatively and thus we do not pay attention to what is given to us during physics lectures and therefore. In this context, I feel frustrated and, therefore, I do not want to learn physics or understand physics problems.

A first-year student (S6F) looked at the issue of society from a different perspective and stressed that the Bedouin life where he has lived affected his views about learning and made him indifferent when he was studying physics the first semester:

> I live in a village about 130 kilometres away from Taif. 95% of its people

> are Bedouins and 5% of them are urbanized, which means that the majority do not care about their learning. I was one among this majority who did not care about their learning and, when I enrolled in physics, I was indifferent about understanding physics problems in the first semester, and this influenced my understanding in the following semester.

In the same context, a first-year student (S5F) explained how the society where students live makes them unaccustomed to thinking and plays a vital role in influencing students' learning of problem-solving:

> I noticed that students are influenced by the society where they live so that they do not want to think about how to deal with problem-solving. They always think the easy way, because they live in a society where everything is provided to them and ready with little effort or thought since they were young.

On the other hand, one of the first-year students (S10F) mentioned another issue that was related to nepotism in university. This issue was considered the result of Saudi culture insofar as nepotism benefits some students and makes them indifferent to studying physics:

> I see that non-Saudi classmates are enthusiastic towards physics learning and understanding physics problems because they know that there aren't any job opportunities for them without graduation, as they have no connections to help them. At the same time, you find that some Saudi students are indifferent and don't take responsibility to understand physics and some of them rely on nepotism after graduation or know someone in the university who can help students pass by providing them with good grades: this nepotism is created by the culture of the society.

Following the presentation of students' opinions about societal influences on them, the analysis of teachers' interviews in both the preparatory-year and the first-year revealed their opinions about the influence of society on various aspects of students' learning of problem-solving in physics. A first-year teacher (T4F) argued that the society where students live affects a child's upbringing in relation to his or her way of thinking:

> Students since childhood are used to being offered everything ready-made without thinking. They don't know to calculate without the calculator. Imagine when we were studying physics like them, we were not introduced to the calculator until the last years of university!

Also, he was surprised that students cannot calculate simple mathematical processes, and believed that this was due to society's culture:

> Imagine that the student in physics is dividing 10/10 and 10/1 using a calculator! The mind became accustomed not to think for years and this is due to society's culture, so students want the solution quickly, without

> following problem-solving steps.

Another first-year teacher (T7F) emphasised on the important role of the environment and the society in which the student lives and that these factors have a role in influencing learning and teaching, as he indicated:

> If the student's community and the environment in which they live cared, this would be reflected in the student's performance and in dealing with solving mechanics problems. As a result, this would reduce the burden on the teacher during explanation.

Likewise, a first-year teacher (T1F) saw that students forget what they studied; he believed that this happened due to the influence of the environment and school:

> When you learn something and succeed in it, then this thing is finished, and you do not need to study it again. This attitude is the result of the influence of the environment and school. Thus, students come to us and have forgotten what they learned about solving physics problems in previous years.

One of the first-year teachers (T4F) mentioned that his teaching method is affected by the habits that students bring from their communities. It is worth bearing in mind that the students come to the university from different regions of Saudi Arabia and, therefore, they belong to different groups within Saudi society in terms of class or tribe and might have different customs and cultures:

> Students gain habits from their communities, such as a school, family and friends, as I do, so when I start teaching my students about physics, I am surprised to find disinterested students because they are accustomed from their society to be like this. This definitely will affect me.

On the other hand, this teacher explained his opinion about how students themselves acted as a factor to encourage or discourage teachers' performance during physics lectures:

> when I find my students excited, this will make me more excited and make me innovate in my explanations to them. If I find students wasting my time with obvious matters related to previous years' issues, making me teach them things they are supposed to know, this will totally affect my performance and my time and effort as well, and this might affect students' understanding of physics problems.

The aforementioned data from the participants, whether students or teachers in both years, agreed on the importance of society's role and its influence on students' learning of problem-solving in physics and the impact of this on understanding physics. This is because students who enrol in university come from different social backgrounds. At university, the family, the school or the community where the student lives appear to impact on students' handling of physic problems as well as their learning. The following section presents the results of the language issues which might impact on students' understanding and thinking in relation to problem-solving in mechanics.

6.7.1.4 Language issues

Half of the student participants (five preparatory-year students and five first-year students), three preparatory-year teachers and two first-year teachers talked about the language issues from different perspectives. In sociocultural theory, language is seen to be of great importance for the mental development of the learner and, hence, has an influence on understanding and solving problems, as mentioned in the literature review chapter. The most important results revealed by the current study are presented below.

Through analysing students' interviews in both stages, the data highlighted the influence of teachers' Arabic dialects on students' understanding, thinking and following the teacher when solving mechanics problems. It is worth bearing in mind that all of the physics teachers come from other countries such as Tunisia, Morocco, Algeria and Egypt. For example, a first-year student (S3F) indicated:

> The numerous accents and languages of the teachers, like the Moroccan and the Algerian, sometimes cause me problems. To be honest with you, the Tunisian, the Moroccan and the Algerian sometimes say vocabulary that is considered weird to some extent. I don't understand them and that's what sometimes causes me difficulty in following the teacher when dealing with the mechanics problems and, therefore, I cannot participate with him.

In the same context, a first-year student (S7F) felt that during the lecture, he focuses on the teacher's dialect instead of understanding the mechanics problems, and he thought this will affect his understanding in solving physics problems:

> Sometimes, I keep thinking about his pronunciation, does he mean this or that? Thus, instead of focusing on understanding the mechanics problem, my focus and thoughts are all upon his dialect and pronunciation. What does he mean?

On the other hand, a first-year student (S10F) referred to the aspect of English language, and that it is considered as an obstacle at the expense of his understanding when dealing with physics problems:

> Sometimes, the mechanics problem in front of me is written in English language. I keep thinking about it, not in terms of the solution method, I think of its translation because understanding the question is half the answer.

In this regard, a first-year teacher (T4F) confirmed a similar point from his experience with his physics students when they deal with physics problems written in English; he described how students try to understand these problems:

> The student doesn't understand the words in the mechanics problem, so his time is wasted in understanding it. The whole problem is in English language, which means mathematics weakness and language weakness. He starts thinking about the words and forgets all about the question. Then, he asks me about the meaning of the word and tries to put it in the sentence to link it to be able to understand.

Likewise, a first-year teacher (T7F) saw that the English language, in addition to the difficulties of understanding physics, caused a burden on students' understanding: "the English language is a barrier to us but it's a temporary barrier until the student understands and figures out the solution of the physics problem; thus, the student has both a scientific and linguistic burden".

Similarly, a preparatory-year teacher (T2P) was asked how the English language influenced students' understanding of physics problems and he indicated that it causes confusion for students understanding in relation to the symbols of physics:

> Sometimes, you are surprised that the student has a problem in physics symbols written in English language when he deals with the solution of physics problems. Because we, as you know, in this country speak Arabic not English. For instance, the students have a problem with the symbols like the letter W - it could be for weight or work - that's what confuses the student.

The preparatory -year teacher (T2P) believed that if students have a good background in English, this will help them to understand: "If the student's linguistic background was good, he would be able to understand these symbols, and this would make things easier for him".

The English language aspect was also reported by another preparatory-year teacher (T5P) who explained how English was a barrier to understanding physics. He clearly indicated that English "is a barrier in identifying the physics problem; this subsequently will negatively reflect on student understanding".

On the other hand, one of the first-year students (S8F) explained how the teachers' use of English words impacted on students' understanding of physics problems and might cause confusion:

> A teacher uses English words in the lecture, and he expects that these English words are understandable to the students, and that's a problem. So, you find that half the students do not understand.

This student described what happened to him when students do not understand English words during physics lectures, and how this affects his focus:

> While I'm following the teacher's explanation, the student beside me doesn't understand these words. He may ask me or ask another student, which makes me lose focus with the teacher in explaining the mechanics problem and makes me lose my thoughts as well. And if I answer the student, I may find the teacher has moved to another idea and that's what makes me unable to follow the teacher in his explanation.

Furthermore, a first-year student (S3F) explained his preference for studying mechanics problems in Arabic, as this would ease understanding the problem: "if the symbols used in mechanics were written in Arabic language, then I would benefit more from it, and as a result understand the solution to these mechanics problems but, instead, I translate them". Also, preparatory-year students (S2P, S13P, S15P, S18P) thought that the difficulty in dealing with solving physics problems was due to the multiplicity of the symbols written in English.

In one of the classroom observations (O5F), when the teacher was explaining the concept of "force analysis", it was noted that he used the symbols in Arabic and wrote them in English. For instance, the teacher mentioned in his explanation during the physics lecture : "we analyse the force into two components " س " [the Arabic letter *seen* used as ***x*** in mathematics in English] and "ص" [the Arabic letter *sad* used as ***y*** in mathematics in English]" while he was analysing the two components on the board, he wrote *x* & *y* and not the Arabic letters.

When I conducted the interview with a preparatory-year teacher (T9P) who was observed in the classroom (O5F) I asked him why he used the symbols in Arabic and wrote them in English. He explained that he did that to help them understand physics problems easily:

> I believe that using the symbols in Arabic language while teaching is the best way to facilitate students' understanding in physics whereas symbols in English make students becomes accustomed to using English language

in their studies later on.

One of the preparatory-year teachers (T8P) believed that using Arabic language in teaching physics symbols can “encourage students to understand physics problems”.

One of the interesting points that emerged from the data relates to the language in which the physics problem is expressed; the physics problems should not contain any complexity, as mentioned by a first-year student (S3F): “If there wasn’t complexity in the language of the physics problem, in a way that mentions what is required and what is given clearly, then it would be easy to solve this problem”. Also, a preparatory-year student (S11P) agreed with S3F about the language of the physics problem, and this constitutes difficulty for him: “the language of the physics problem is considered a difficulty to me sometimes and because the question’s format isn't as clear as we would like”. In addition, when asking the students about the FCI and MBT tests that had been distributed to them, a first-year student (S19F) indicated that the language used in the questions and the questions’ presentation was different from what they were accustomed to in university and that it required some new sorts of thinking.

In the same context, one of the preparatory-year teachers (T5P) confirmed the importance of the structure of a physics problem and the use of clear language to understand it: “the format of the problem and the use of suitable language has a very important role in understanding the problem”.

6.8 Summary of the Chapter

In this chapter, qualitative data collected from multiple sources (interviews, classroom observations and think aloud protocols) were analysed and six themes emerged from the analysis: (1) perspectives on problem-solving, (2) problem-solving strategies used by students, (3) lack of basic knowledge at different levels of the education system, (4) perspectives on physics teaching methods, (5) institutional factors affecting students’ learning of problem-solving in physics, and (6) sociocultural factors affecting students’ learning of problem-solving in physics. The results of each theme were highlighted in a comprehensive manner in order to present a detailed picture of the perspectives of both teachers and students in the preparatory- and first-year regarding problem-solving in the Saudi context.

Chapter Seven: Discussion

7.1 Introduction

This chapter discusses the main findings of this study in light of the literature in general and in line with sociocultural theory in particular. Therefore, it discusses problem-solving strategies used by students and their understanding of basic concepts. Moreover, lack of basic knowledge at different levels of the education system are discussed. Then, perspectives on physics teaching methods are discussed. Also, this chapter moves on to discuss institutional and sociocultural factors affecting students' learning of problem-solving in physics.

This study was conducted to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. Thus, this study attempted to address the following research questions:

1. To what extent does the level of Taif University preparatory-year and first-year students' understanding of the basic concepts in mechanics allow them to solve physics problems adequately?
2. What strategies are used by Taif University preparatory-year and first-year students when they deal with physics problems, and why do they use such strategies?
3. What are students' and teachers' perceptions about physics teaching methods?
4. What are students' and teachers' perceptions of the institutional factors impacting on students' learning of problem-solving in physics?
5. What are students' and teachers' perceptions of the sociocultural factors impacting on students' learning of problem-solving in physics?

7.2 Discussion of the main findings

This section discusses the main findings presented in Chapters Five and Six as presented in the following Diagram 7.1. These relate to problem-solving strategies used by students, student understanding of basic concepts in solving physics problems, lack of basic knowledge at different levels of the education system, perspectives on physics teaching methods, and institutional and sociocultural factors impacting on students learning to solve problems in physics. These will be discussed in this chapter in order to understand why students have difficulties in solving physics problems and why they seem to be unable to solve physics problems.

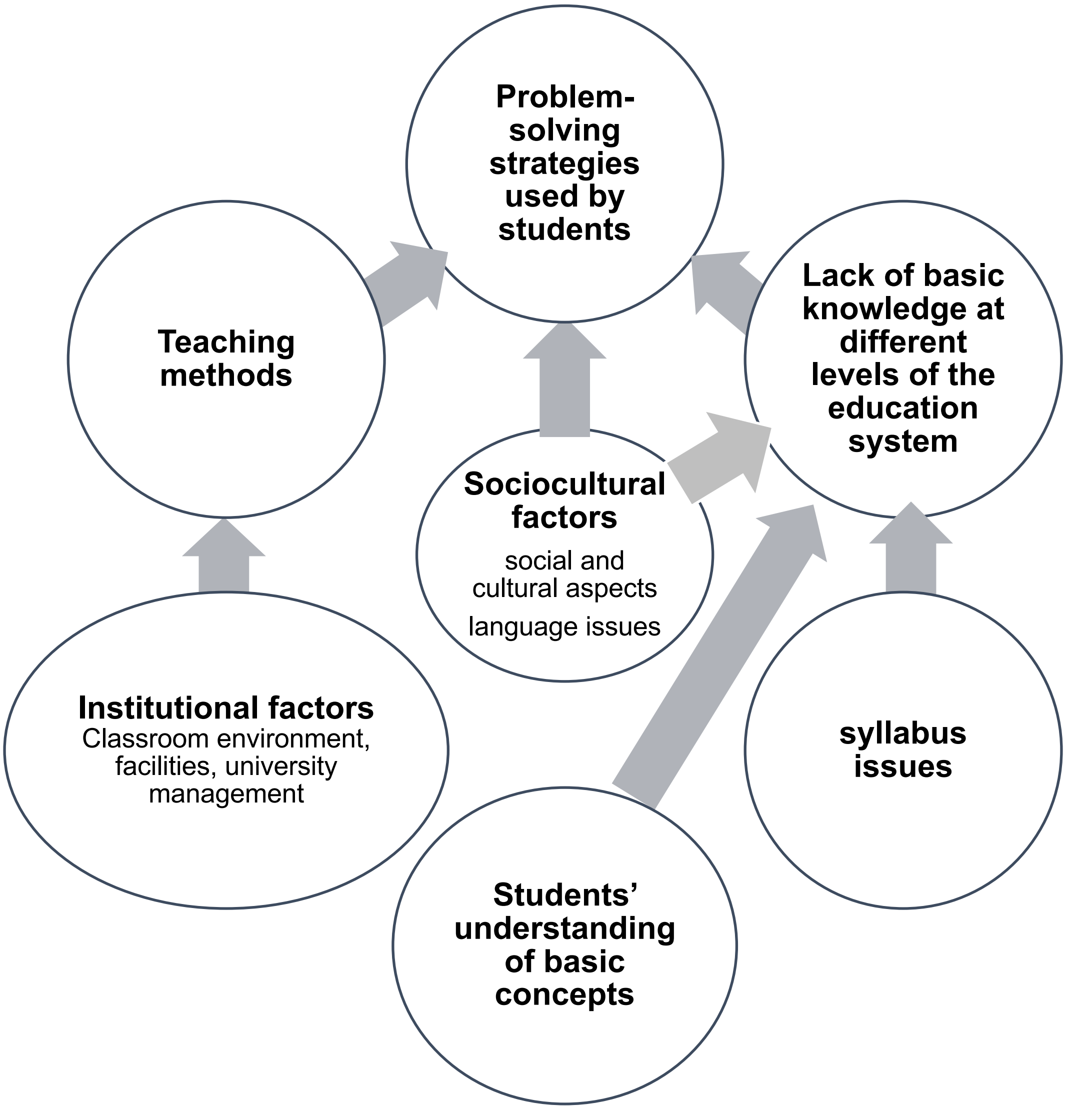

Figure 7.1: Main findings of the current study

7.2.1 Problem-solving strategies used by students

This section relates the first two research questions. It is worth mentioning that problem-solving consists of four steps: (1) understanding the problem, (2) devising a plan, (3) carrying out the plan, and (4) looking back. For the purpose of the think aloud protocols, the following mechanics problem was given to the participants:

> A box weighs 562 Newton on a tilted surface at a 30-degree angle. The force of gravity has two components, one perpendicular and one parallel

to the incline. Find the two components of the weight force.

Hence, in this section, the steps of problem-solving are discussed in light of the interviews with students and teachers from both years and think aloud protocols with students.

7.2.1.1 First step: understanding the problem

The data analysis of the interviews with students and teachers and the think aloud protocols with students revealed that students found it difficult to understand the problem which was given to them during the think aloud protocols. Some first-year students gave some explanation related to understanding the problem, whereas four preparatory-year students gave up trying to explain the problem, while other preparatory-year students tried to understand and solve the problem, but they could not. Researchers (e.g. Byun et al., 2010; Reddy & Panacharoensawad, 2017; Ogunleye, 2009) have found that certain factors may hinder students' problem-solving skills in physics, such as the students' inability to fully comprehend the problem they are faced with. In a study conducted by Chi et al. (1989), it was found that weaker students struggle to give explanations and find it hard to explain additional features of the laws while solving a given physics problem, as they have a weak comprehension of what they read in the physics problem. Nevertheless, the problem which was given to the participating students was taken from a secondary school physics book.

It was noticed that, while they were solving the physics problem, students were not asking themselves a set of questions related to this step, as suggested by Polya (1957), which might facilitate the understanding of the problem. Rather, they seemed to focus on finding the data given and thought straight away about the substitution in the equations without putting enough focus on understanding the problem and physics concepts. This was similar to Zewdie (2014), who found that students do not spend much time understanding a physics problem. Moreover, Docktor et al. (2015) pointed out that students actually perceive the equations as a fundamental key to solving physics problems and tend to ignore physics concepts. In this regard, students need to ask themselves appropriate questions in order to engage their cognitive processes in relation to problem solving (Özsoy & Ataman, 2009), as problem-solving requires using high-level of cognitive skills (Zewdie, 2014). Consequently, cognitive and metacognitive skills need to be given great importance in order to boost students' awareness of their learning processes when dealing with physics problems.

Also, as mentioned in the qualitative findings chapter, during think aloud protocols, students from both years drew diagrams that revealed their lack of understanding of the physics problem. Thus, preparatory-year students showed that they did not have basic physics knowledge about "the two components of the weight force" and they could not draw the components of the weight force correctly because they did not understand the concept (components of the weight force). On the other hand, the first-year students did manage to draw the components. This can be explained by the fact that first-year students are considered as specialists in physics unlike the preparatory-year students who do not specialise in physics, even though the physics problem was taken from a secondary school physics book. However, first-year students made a mistake when they tried to analyse the two components of the weight force on the diagram; they multiplied the weight by the cosine of the angle 30^0 on the perpendicular axis, except for four students who analysed the two components correctly but did not find the solution because they said that they did not understand what to do next. As discussed later in this chapter (see section 7.2.2), this might be related to students' lack of basic knowledge of physics concepts, which might hinder their understanding of physics problems. This argument is supported by the results from the quantitative methods (FCI, MBT questionnaire). The mean percentage scores on the FCI test in all the categories (kinematics, first law, second law, third law, superposition principle, kinds of forces) measuring the participants' understanding of the basic concepts in mechanics were well below 60%. Also, some students from both years during the think aloud protocols mentioned that they did not understand physics concepts such as the force of gravity or the two components of the weight force.

This strongly suggests that students' comprehension of Newtonian concepts is inadequate for successful problem-solving. Therefore, the mean percentage scores on the MBT and its categories (kinematics, general principles, kinds of forces) were also below 60%. Also, the correlation between students' understanding of the basic concepts in mechanics and their problem-solving skills in mechanics was found to be a medium-sized one, and statistically significant. This finding tends to suggest that students' understanding of the basic concepts in mechanics is insufficient for successful problem-solving. Therefore, students during think aloud protocols found difficulty in understanding the problem, and none of the students could solve the physics problem provided. These findings were found to be consistent with what is reported in the literature (e.g. Kim & Pak, 2002; Park & Lee, 2004; Zewdie, 2014) that students have difficulties in understanding basic concepts of mechanics when they deal with physics problems, emphasising the importance of physics concepts in relation to solving physics problems. Also, Chi et al. (1989) pointed out that weak students are often unable to clarify example-exercises to themselves. In instances where they are able to do so, their clarifications tend to be detached from their comprehension of the principles and concepts in question. Eshetu and Assefa (2019) emphasised that students need to possess physics concepts used for solving problems in order to enhance their understanding of physics problems.

Moreover, all the teachers from both years emphasized that the students had difficulty in comprehending physics problems. However, it was also noticed through the classroom observations that the teachers asked questions without giving students the opportunity to think or ask questions and that the teachers often answered the questions themselves. The exception to this was in one of the preparatory-year classroom observations where it was noticed that the teacher discussed the understanding of the mechanics problem with his students using a graph to clarify the requirement. Also, he checked the students' understanding through asking questions, such as "What is the unknown in the physics problem?" and "What are the data in this problem?" Therefore, this style of teaching (teachers asked questions without giving students the opportunity to think or ask) hindered the interaction between students and teacher, or between the students themselves, so students were denied any opportunity to question their teachers. Ates and Cataloglu (2007) mentioned that traditional teaching methods do not help students to understand mechanics problems, despite the fact that such interaction may contribute to the development of the cognitive ability to understand physics problems, because social interaction develops cognitive abilities (Wallace et al., 2012). According to sociocultural theory, through a process of interaction and transformation between people within the context, individuals change their responses to establish different kinds of meaning (Stevenson, 2004). In the Saudi context, a number of studies (e.g. Alghamdi, 2013; Alqhatani, 2013; Al-shannag, Tairab, Dodeen, & Abdel-Fattah, 2013) have confirmed that teachers relay mainly on traditional practices such as assisting students to memorise physics information rather than encouraging them to ask questions or interact with their teachers during physics lessons. Also, the lack of basic physics knowledge acquired from school (as discussed later in this chapter, see section 7.2.2) may, in this study, be related to the teaching methods which rely on memorisation, as students merely memorise knowledge or procedures and try to replicate the same procedures with any physics problems they face, without proper thought. Several studies in the Saudi context (e.g. Alqhatani, 2013; Asseri, 2010) have found that physics teachers rely on traditional teaching methods, which is one of the reasons for the weakness of students in the acquisition of physics concepts.

7.2.1.2 Second and third steps: devising a plan and carrying out the plan

Through conducting interviews with all students and based on the think aloud protocols using the same mechanics problem given above, the results show that the students did not seem to know how to devise a plan to solve a problem. For example, students started to search for the givens from the mechanics problem and to think immediately about the law without attempting to plan to solve the problem. Also, a first-year student mentioned that he did not devise a plan when he solved physics problems and started to solve the problem immediately without any plan, because he was not accustomed to using a plan. This was consistent with Zewdie's (2014) study, which found that students do not spend much time devising a plan to solve physics problems.

Moreover, the qualitative data analysis (interviews, think aloud) revealed that students had the perception that extracting the data and finding the required part of the mechanics problem is considered as devising a plan. Therefore, from the statements of the students from both years, in the think aloud protocols, students did not seem to know how to carry out a plan to reach the solution to the problem. Also, the classroom observation findings revealed that the teachers did not focus on devising a plan but on extracting the data, finding the required part of the problem and finally substituting the law without giving enough time to explain how devising a plan could be used to solve problems. It is worth noting that "planning involves the selection of appropriate strategies and the allocation of resources that affect performance. Examples include making predictions before reading, strategy sequencing, and allocating time or attention selectively before beginning a task" (Schraw, 1998, p.115). However, only one preparatory-year teacher asked his students a set of questions/statements such as "What does the requirement of this problem remind you of?" or "Let's apply the given data to know the missing part" in order to help his students to plan and better understand the problem.

Based on the findings above, it can be argued that the students were not accustomed to following the scientific approach, as in having problem-solving steps, since their teachers used traditional teaching methods which made them rely on memorisation rather than thinking. Therefore, throughout their studies in school, students might not have learned to use these steps to solve physics problems. In this respect, Alhadlaq et al. (2009) stated that, in the Saudi context, high-school science education is characterised by the use of memorisation of equations and students following "recipes" to solve problems. Moreover, Forawi (2016) mentioned that "many of our present education majors have come through systems where the curriculum was more fact-driven, that is, taught using traditional teacher-directed methods" (p.53).

Furthermore, the school context might contribute to the students' focus on passing examinations in secondary school rather than on thinking skills. As a result, they do not pay enough attention to these skills due to the fact that their teachers in school encouraged them to do so, as mentioned earlier by students from both years in the findings chapter. The findings of the current study concur with Al-Qahtani's (1995) study which investigated the factors preventing the teaching of thinking skills in the Saudi context; the study found that one of these factors is the concentration on the examination and that the examinations themselves encourage students to recall and memorise rather than think. Also, Mansour (2010) in his study in Egypt found that science teachers at the beginning of the school year are concerned about the examination, which makes students worried and forces them to concentrate on remembering knowledge. However, science lessons should aim at engaging students in a process that allows them to think, innovate and enhance their thinking skills in order to resolve issues and problems that they encounter rather than just providing students with information, as reported in the literature (e.g.

Sawafetah, 2008; Yaseen, 2013). In turn, students may be more likely to make the most of these skills and be ready to make valuable contributions to society's progress (Alsayeh, 1997). Accordingly, it is necessary for educational systems to transition from merely providing information to enhancing thinking skills and focusing on them, which in turn may help students to solve physics problems. In this context, McGregor (2007) confirmed that there is strong evidence that programmes which concentrate on teaching thinking skills can improve students' problem-solving abilities, their academic performance and cognitive processing skills.

Hence, as mentioned in the qualitative findings chapter, students immediately attempt to substitute the data in the physics problem without any consideration of devising a plan. This result is consistent with what Ali, Ibrahim, Abdullah, Surif and Saim (2014) found in their study in Malaysia, that university students prematurely jump to substitute data into a physics equation without giving enough time to reading and analysing the physics problem. This result is also similar to that of Zewdie (2014), who found that students do not spend much time to devise a plan to solve physics problems.

Nonetheless, attempts have been made to develop students' thinking through the Developing Science and Mathematics Curriculum Project for all stages of the Saudi general education system (primary, intermediate, secondary). As mentioned in Chapter Two, students seem to be at a beginner's level in physics, as also confirmed by Alshaya et al. (2015) who conducted a study in Saudi Arabia to evaluate this project. They concluded that a majority of participating students could be considered as beginners with regards mathematical knowledge, physics and chemistry in many stages of the education system. In terms of cognitive and thinking skills, their findings suggest that more than half of the students are also at the beginners' level in mathematics and most science specialities. In the above study, the National Centre for Assessment in Higher Education examination recorded that, in 2012, students who had been taught the experimental curriculum obtained significantly higher scores compared to those taught the regular curriculum currently implemented in the Kingdom's schools. Therefore, based on the study's result, the new curriculum was thought to contribute to the improvement of students' achievements.

Furthermore, several Saudi studies (e.g. Alghamdi, 2013; Alqhatani, 2013; Alshannag et al., 2013) have confirmed that many school teachers rely on traditional practices such as assisting students to memorise physics information rather than encouraging them to ask questions or think. Therefore, students might be accustomed to relying on their teachers and memorising scientific knowledge without being trained to be aware of their thinking processes or having guidance in how to use thinking during their studies in order to understand physics problems. Therefore, when students move from school to university, they are ill-prepared in terms of thinking processes, physics problem-solving and devising problem-solving plans. This may explain why the students seemed unaware of how to devise and carry out a plan to solve a problem. Grizzle-Martin (2014) emphasised that teachers should focus on cognitive and metacognitive strategies during their teaching. Therefore, teachers need to teach their students the modes of thinking when solving physics problems in order to guide and organize students' thinking to achieve the desired goals in their learning.

In addition, teachers' practices (traditional practices such as a lecturing approach in delivering information to students) at the university impact on students' thinking while solving physics problems. As mentioned in the Qualitative Findings Chapter, all university teachers in both stages are specialists in physics but have not received sufficient formal training in the pedagogical aspects related to the teaching and learning of physics, nor have they attended workshops on thinking or problem-solving skills, except four teachers who just attended workshops on teaching methods in general. However, such workshops are not related to thinking or problem-solving skills. Also, based on the classroom observation findings, teachers did not seem to pay enough attention to implementing the steps of problem-solving. This did not encourage students in their understanding of physics problems or in their learning how to devise and carry out plans to solve problems. This is an indication of the lack of university teachers' professional development, which may impact negatively on students' learning and their use of problem-solving steps. Therefore, teachers' professional development is an essential element that needs to be implemented in university programmes, and that these programmes should "develop learning activities in the CPD programmes that encourage and facilitate teachers to reflect on their learning and practices"

(Mansour et al., 2014, p.970). Hence, the findings of this study in relation to the lack of professional development of university teachers seem to contradict the objectives of the Ministry of Education in Saudi Arabia which are, among others, to develop the criteria needed for the selection and qualification of teachers, develop their competencies and motivate them.

7.2.1.3 Fourth step: looking back

The student participants in the preparatory- and first-year, when presented with the previous mechanics problem, did not implement the step of 'looking back', except a first year-student. This is consistent with what has been reported in the literature (e.g. Reif & Larkin, 1976; Shareeja & Gafoor, 2014; Zewdie, 2014), that students rarely spend much time in 'looking back' when they deal with physics problems. They do not look back and ask themselves whether the result is close to the right answer. In addition, through classroom observations, this step was not apparent in the teachers' explanations of the solution of the mechanics problems. This comes with the exception of a preparatory-year classroom observation where the only evaluation aspect used by the teacher was checking that the measuring units used in the solution made sense, which he discussed with the students. Nevertheless, this step is essential as it helps students consider the solution and recognize any mistakes they might have made (Alzahrani, 2016).

The absence of this step (looking back) among the participants' problem-solving strategies could be related to several factors. Firstly, students' lack of basic physics knowledge and physics concepts seems to be a significant factor because, if students do not have the basic physics knowledge and concepts, they will not understand the physics problems and, therefore, will not be able to use the other steps of problem-solving such as looking back. In this regard, Peña-Ayala and Cárdenas (2015) stressed that the purpose of knowledge is to direct and adjust actions towards goals, so knowledge is considered as the basis of cognitive activity. As mentioned by Zewdie (2014), the steps of problem-solving such as 'looking back' are considered as part of a process that requires cognitive skills. In addition, as mentioned in the qualitative findings, teachers in school or at university use traditional teaching methods which encourage students to rely on memorisation rather than thinking or following the steps of problem-solving. Therefore, students at the end of their studies might have a lack of basic physics knowledge. Van Heuvelen (1991) mentioned that "students, at the end of their conventional study, have little structure to their knowledge. Their understanding consists of random facts and equations that have little conceptual meaning" (p. 894).

Secondly, as university teachers in both years had not received formal training, or received insufficient training, in terms of the pedagogical aspects related to thinking skills and physics teaching, their performance had a negative impact on students' implementation of problem-solving steps. According to Qablan, Mansour, Alshamrani, Aldahmash and Sabbah (2015), teachers who have opportunities to learn will be able to provide more opportunities for their students. In other words, because all the teachers in this study seemed to lack specialised understanding of the pedagogical aspects related to the teaching and learning of physics, it is likely that their students would not receive enough guidance to solve physics problems or to use the steps of problems solving, which would affect their performance in problem-solving.

Thirdly, students in the current study did not seem to have an adequate understanding of the steps of problem-solving as, when asked about these steps, they talked about general issues such as knowing the barriers, searching for alternative solutions and using the laws of physics to solve problems. In addition, only one first-year student mentioned 'understanding the problem' and one preparatory-year student stated, 'searching for an alternative plan'. However, none of them mentioned the step of 'looking back'. This indicates a lack of awareness of the importance of the steps of problem-solving, as mentioned by students from both years in the qualitative chapter. Because some students did not see the significance of using these steps in solving physics problems, this might reflect negatively on using skills such as 'looking back'. Since a fundamental aim of physics as an academic subject is the solving of problems, these types of tasks form an important part of most physics' classes at various educational levels (Kim & Pak, 2002). So, using the steps of problem-solving needs to be considered in physics education in the Saudi context in order to strengthen students' awareness of their learning when they are dealing with solving physics problems.

Fourthly, the results of the students' interviews from both years (three preparatory-year students and one first-year student) showed that the aspect of time was perceived as an obstacle to implementing problem-solving steps. Research points to the importance of dedicating enough time to give students the opportunity to think about their learning (Al-qahtani, 1995; Rodrigues, 2005). So, giving students enough time would give them the opportunity to think about their thinking and evaluate the processes they used in solving a problem, and help students to “be aware of the problem-solving process” (Sahin & Kendir, (2013, p.1777).

The following section discusses the data in relation to students’ lack of basic knowledge at different levels of the education system and how this may affect students’ learning of problem-solving in physics.

7.2.2 Students’ lack of basic knowledge at different levels of the education system

This section relates to the second research question with regards to why students use these strategies (as mentioned in the previous section). The analysis of the interviews from students and teachers in both years and one classroom observation revealed the lack of basic physics knowledge acquired from school. Indeed, this aspect seemed to reflect negatively on students’ understanding of physics and in their approach to solving physics problems. This is consistent with what was found in the literature (e.g. Byun et al., 2010; Milbourne & Wiebe, 2018) that certain factors, such as an insufficient knowledge base, may hinder students’ problem-solving skills in physics and that students with more physics content knowledge are more successful in solving physics problems, and therefore face fewer obstacles. In this respect, the interview findings of the preparatory-year students and teachers revealed that the university teachers did not pay enough attention to explaining certain mechanics problems as they may have believed that students had acquired the necessary basic physics knowledge from school to enable them to solve such problems; therefore, this had a negative effect on students’ understanding of physics.

During the interviews, students expressed the belief that school is supposed to give them basic physics knowledge and yet they realised that they had been taught to memorise rather than think when learning physics, and teachers mentioned that continuous evaluation in school had enabled students to succeed without any mastery of the basics of physics. Hence, it seems that schools do not teach physics properly and that students come to university lacking basic physics knowledge.

As widely reported in Saudi Arabia by a number of studies (e.g. Alghamdi, 2013; Alhadlaq et al., 2009; Alhammad, 2015; Alqhatani, 2013; Al-shannag, Tairab, Dodeen, & Abdel-Fattah, 2013; Litvin, 2010), many teachers rely on traditional practices such as assisting students to memorise physics information rather than encouraging them to think; also that teaching and learning procedures are teacher-centred where students rely on their teachers to organise their learning. Another study, conducted in Ethiopia, found that college students were often unsuccessful in solving problems during examinations, even problems which had been previously solved in class. The reasons for students' inability to solve physics-related problems were found to be varied and included the defects of traditional teaching approaches, students' nervousness, their low level of interest in the subject or their insufficient knowledge of mathematics (Zewdie, 2014).

Secondly, the reasons for the weakness of the students in basic physics knowledge may also be the negative effects of continuous evaluation (as mentioned by two first-year teachers and a preparatory-year teacher) implemented in all primary years in Saudi Arabia. Therefore, the background of students in the elementary stage may be weak in terms of literacy, mathematics and science, which are considered the bases upon which physics depends in the later stages of education. Even though some studies have reported that formative assessment has positive effects on achievement, such as Cauley and McMillan (2010), who argued that student motivation and attainment are strongly influenced by the effective use of formative assessments, this contradicts the findings of the present study. The implementation of continuous evaluation at the primary level has been seen to have a negative impact on students' achievement (Al-Sadawi, 2011), with a possible reason being that some teachers do not possess sufficient knowledge of the goals of continuous evaluation. Perhaps teachers were unable to determine the students' levels of mastery of the skills they were supposed to be gaining during their learning. In addition, the inability on the part of some teachers to reconcile their teaching methods and the new methods of evaluation might have led to ignoring higher-order thinking skills, as they mainly focused on memorisation.

Furthermore, students have weaknesses in other thinking skills, such as analysis, comprehension and evaluation, which should be developed with these important age groups (primary education). This weaknesses in other thinking skills has lowered the academic achievement of students in the primary stages and, therefore, may have negatively impacted on the subsequent stages (Almutairi, 2009; Alqurashi, 2011; Al-Sadawi, 2011). Moreover, in 2015 the results of eighth grade students in Saudi Arabia on the Trends in International Mathematics and Science Study (TIMSS) confirmed this weakness in terms of achievements in science and mathematics, as Saudi Arabia ranked 35 out of 39 participating countries, and 45 out of 47 with respect to fourth-graders' results. Also, comparing these results with other neighbouring countries such as Oman (which ranked 29 out of 39 for grade 8 and 42 out of 47 for grade 4), Qatar (which ranked 26 out of 39 for grade 8 and 41 out of 47 for grade 4) or Bahrain (25 out of 39 for grade 8 and 38 out of 47 for grade 4), a significant difference can be observed.

Thirdly, another aspect that may explain students' lack of basic knowledge in physics relates to the transfer of students from different educational contexts, for example from school to university, which could affect their identity as learners of physics. Participating students discussed their experiences at school saying that they were accustomed to memorising without a challenge to their thinking and that they were accustomed to having physics units and topics removed from the syllabus. Therefore, students anticipated finding themselves novice learners in physics when they moved to the university context, because they were required to reshape their learning identity to gain the ability to make changes in their practices while learning physics and to become active learners using reasoning skills while dealing with physics problems. This idea is supported by Wingate's (2007) argument that an understanding of the role of the learner and the implications of this in higher education is required of students. Students must aspire to learn independently and be responsible for their learning. Furthermore, instead of being passive recipients of knowledge, as is common in secondary schooling, learners must seek to engage in an active and critical manner.

In a similar context, Hayes, Mansour and Fisher (2015), who conducted research in Bahrain, a country with a similar background to Saudi Arabia, found that medical students who had developed certain identities as learners in school experienced changes when entering university, as they found themselves uninitiated learners in an unfamiliar environment. This led to uncertainty among such students regarding the means of achieving progress in their new setting.

The data collected from teachers in both years revealed the lack of basic knowledge of preparatory-year students in physics and also the lack of basic knowledge of first-year students in mechanics. The data also showed the students’ lack of basic physics knowledge acquired from university as teachers mentioned that the academic standards of physics students over recent years was lower than in the past. Buschhüter, Spoden and Borowski (2017), in a study conducted in Germany with physics freshman, found a fundamental decrease in physics knowledge, reporting that the university teachers believed that students were not as gifted as they had been in previous years.

In this context, as explained in the Context Chapter, results from Taif University had shown a notable decrease in physics achievement over the period 2006-2015 in the first-year mechanics course and in the preparatory-year general physics course. Interestingly, this lack of basic knowledge seems to be reflected in the level of pre-service teachers in school and, in turn, in the students’ level itself. The qualitative findings confirmed this argument, as a preparatory-year teacher mentioned that a physics pre-service teacher who graduated from the university was likely to have a lack of basic physics knowledge, which could affect his pupils’ understanding. This, according to this participant’s experience, was what happened with his son in secondary school where a pre-service teacher taught the unit of wavelength measurement incorrectly and said it is the Hertz.

The lack of teacher awareness of the nature of the teaching and learning of physics in the two contexts of school and university may be one of the causes negatively affecting students' acquisition of basic knowledge in physics. Therefore, this might lead to the lack of readiness of students to effectively solve problems at university. This idea was confirmed by students from both years and from preparatory-year teachers’ interview findings insofar as university teachers believed that students had already acquired basic knowledge of physics problems and mechanics concepts from school and, therefore, they did not pay much attention to explaining mechanics problems to their students. This seems to be reflected negatively in students' understanding of physics. Moreover, teachers explained that they were surprised when students did not appear to have studied certain topics connected to the physics lessons taught at university. This seems to be consistent with research that has reported the importance of communication between school and university in order to find out the reality of the school environment and the education achieved there (Saito, Imansyah, Kubok, & Hendayana, 2007).

The data obtained in this study point to very similar issues with regards to the teaching of mathematics. Indeed, the analysis of interviews with students from both years revealed another important aspect regarding the students' lack of basic knowledge. The findings suggest that most difficulties facing students while dealing with physics problems are caused by lack of basic mathematical knowledge. In addition, students from both years believed that having basic mathematical knowledge could facilitate solving physics problems. Moreover, all teachers confirmed that their students lacked basic mathematical knowledge and the obstacles students faced were related to their lack of basic mathematics. A classroom observation confirmed that students in the preparatory-year made basic mathematical errors, such as in conversion from metres to centimetres or in multiplications and divisions when they participated with their teachers. This is consistent with other studies (e.g. Byun et al., 2010; Niss, 2017; Ogunleye, 2009; Reddy & Panacharoensawad, 2017; UK Physical Science Centre, 2008) which found that certain factors may hinder students' problem-solving skills in physics, including an inadequate level of mathematical skills.

Perhaps the traditional teaching approach used in schools is one of the reasons that led to students' lack of basic mathematical knowledge, as suggested by studies conducted in Saudi Arabia (e.g. Almalki, 2012; Alshahrani, 2009; Alzahrani, 2017) that found that the traditional methods used in the teaching of mathematics play a vital role in hindering students' learning. Moreover, the mathematics results of Saudi students on the TIMSS in 2015 in grades four and eight confirmed such weakness in terms of mathematical achievement, so that Saudi Arabia ranked 39 out of 39 participating countries for the eighth grade and 46 out of 49 countries for the fourth-grade. Thus, the weakness of students in mathematics during their learning in all school stages until they join university is reflected negatively in their understanding of physics problems, as physics problems in general and mechanics problems in particular rely on mathematical knowledge and skills such as calculus, trigonometric functions or the use of a scientific calculator.

The data collected from interviews of students of both years and preparatory-year teachers demonstrated that the lack of basic physics conceptual understanding in relation to problem-solving was one of the factors which caused confusion in understanding physics concepts. For example, a preparatory-year student mentioned clearly that he did not understand the physics concepts but memorised them without deep understanding. This result is consistent with Malik et al. (2019) who pointed out that students predominantly memorize physics concepts without comprehending. Also, another first-year student confirmed that his knowledge of physics concepts was shallow. In addition, two-preparatory-year teachers emphasised that the students seemed to have no understanding of physics concepts. Hence, it seems from the data that there is a relationship between understanding physics concepts and solving physics problems, which has also been reported elsewhere in the literature (Hestenes et al., 1992; Kim & Pak, 2002). This can be seen clearly in the quantitative findings when looking at the FCI and MBT questionnaires in Chapter Five, where the mean score on the FCI test to measure preparatory-year and first-year students' understanding of basic concepts in mechanics was well below 60%. This strongly suggests that students' comprehension of Newtonian concepts is inadequate for successful problem-solving. As a result, the mean score on the MBT to assess students' problem-solving skills in mechanics was also below 60%.

I believe there are many reasons behind the lack of basic physics conceptual understanding in this study. Firstly, students come to class with previous ideas and experiences based on what they have learned in their schools and their daily lives or perceived about natural phenomena. In the Saudi context, Alhammad's (2015) study argued that "the local Saudi society and culture affected students' understanding of scientific concepts which contradict with the scientific perspective" (121). In this context, according to Haenen (2003), Vygotsky distinguishes between the development of everyday concepts and academic ones by explaining that everyday concepts are grounded in the life experiences while academic concepts tend to develop during the learning process. Nonetheless, they also note that the two types are linked.

Secondly, teachers might introduce physics concepts or ideas without giving their students enough time to ponder or ask what these concepts or ideas mean. Meanwhile, students may give wrong answers without being corrected by teachers and, therefore, this might create confusion or misconception among students about their learning. This does not constitute good practice in terms of scaffolding, in addition to the fact that it may not confirm their understanding of physics problems or build their knowledge of physics. It has been argued by Bigozzi, Tarchi, Falsini and Fiorentini (2014) that physics should be taught in a slow, gradual manner in a way that is adapted to the developmental characteristics of the learners. While they do not call for reducing the content covered, they argue for focusing less on definitions and formulae and paying more attention to developing students' conceptual understanding (ibid).

Thirdly, the interview findings from students of both years and classroom observations revealed that most teachers used traditional practices such as a lecturing approach in delivering the information to the students. These traditional teaching methods, widely used today in schools and universities in the Saudi context, as reported in literature (e.g. Alhadlaq et al., 2009; Alhodithy, 2009; Alkhowaiter, 2016), play a role in encouraging students to memorise information and concepts without a deep understanding of what these concepts mean. According to Alhammad (2015), science education in Saudi Arabia was still using traditional teaching methods, and students mainly relied on textbooks and teachers, whereas science education in western countries had moved to use constructivist approaches and which give students the opportunity to use their experience and knowledge in understanding scientific concepts. Instead, the teacher should use different teaching methods such as cooperative learning (as suggested by two students from both years) when working on physics problems to encourage students to share their ideas with each other because this kind of learning might make the most of students' Zone of Proximal Development. According to Harskamp and Ding (2006), collaborative learning, in comparison with individual learning, significantly enhances problem-solving skills in physics, whereby participants (99 secondary school students from Shanghai) were administered a pre-test and a post-test and were asked to solve six physics-related problems. The results showed that students who learnt to solve physics problems in collaboration with others reached higher scores than those who learned these skills individually.

However, a certain knowledge of physics concepts is necessary for students in order to approach problems adequately in a group discussion, but such discussions present productive opportunities and aid students' learning and comprehension of physics principles and concepts (Benckert & Pettersson, 2008). The following section discusses the data in relation to the physics teaching methods and how they may affect students' learning of problem-solving in physics.

7.2.3 Perspectives on physics teaching methods

This section relates to the third research question with regards to teaching methods. The results of the interviews with students of both years indicate that teaching methods play a vital role in students' understanding and interest in physics, which helps them understand how to solve physics problems. The data from interviews with students demonstrated that the teaching methods employed by physics lecturers influenced their understanding, that their teachers adopted a lecturing approach, but that the students wanted them to use other methods, like cooperative learning or brainstorming. As a result, according to the interviews conducted with students and based on classroom observations in both years, the mechanics problems were presented directly without relating them to reality and without discussing the physics terms included in the problems, except four class visits where the teachers linked the problems to daily reality.

Also, if teachers connected what is taught with reality (daily life), this would help students understand physics problems, a notion supported by Park and Lee (2004). The latter study concluded that many students and university physics teachers wanted to learn or teach solving physics problems through everyday contexts, as this helped students to understand the basic concepts. Alshaya (2014) emphasised that physics problems need to be connected to daily life in order to overcome the difficulties facing students to understand these problems.

A number of classroom observations from both years confirmed that the university teaching methods encouraged students to memorise. According to sociocultural theory, use of a diversity of teaching methods such as cooperative learning or brainstorming, would help students to achieve improvement in their Zone of Proximal Development. This could happen through the use of various teaching methods, including discussion and teacher support for students, and encouraging students during the explanation of physics problems, particularly mechanics problems. Clapper (2015) notes that the instructor in the ZPD can help students to solve problems through the use of case studies, discussions or demonstrations. Also, the teacher, through discussions and interactions (between the teacher and students and between students themselves), can explain to the students the steps of problem-solving using charts and physical symbols and by linking physics problems to students' daily life. This would constitute good practice in terms of scaffolding. This is supported by Andersen and Nielsen's (2013) claim that teachers can promote students' motivation in several ways, such as teaching through the use of real-life examples to demonstrate scientific concepts, challenging student thinking through dialogue involving questions and comments to responses, making assessments which motivate risk taking and support reflection on mistakes and assisting students through modelling and scaffolding.

One of the most prominent results of the present study is that more than half of the teachers from both years (three preparatory-year teachers out of five and three first-year teachers out of five) had not attended any training courses or workshops on teaching or on thinking skills. This might be one of the reasons for their lack of awareness of the importance of diversity in teaching methods and their reliance on traditional methods which depend on memorisation. This is because all the teachers in both stages were science specialists and had not studied the pedagogical aspects of teaching methods, and this affected their teaching practice in terms of organising and representing physics content and applying methods which encourage students to participate during physics lectures.

Alkhowaiter (2016) found that Saudi university teachers needed to develop their skills in terms of teaching methods as she claimed that university teachers saw themselves as having reached sufficient knowledge and a high position and did not then want to develop their teaching skills. However, the National Science Teachers Association (NSTA) in the USA argued that effective science teachers consistently attempt to enhance their understanding of the constantly evolving body of knowledge both in terms of scientific knowledge and pedagogical knowledge (NSTA, 2012). Also, Qablan et al. (2015) emphasised that teachers who have opportunities to learn will be able to provide more opportunities for their students.

The findings of the current study are consistent with a number of Saudi studies (e.g. Alhreashi & Alkakee, 2005; Alkhowaiter, 2016; Alsemeah, 2005; Alzaher, 2002) that showed the lack of professional development of university teachers and the need to take their professional development into account in order to improve their performance. Therefore, professional development is an essential element that needs to be considered in the university programme in order to "encourage and facilitate teachers to reflect on their learning and practices" (Mansour et al., 2014).

The results of this study also confirm that the aspect of time is one of the reasons why teachers rush through their explanations of physics problems without giving enough time for discussion or cooperative work. The focus during a lecture in higher education is often on learning the content and, therefore, students have little time to ask questions or process the information (Forawi, 2016). As a result, this negatively impacts students' learning and understanding of the solution of physics problems. The reason for the lack of time for discussion might be the length of the physics syllabus. Indeed, teachers may fear that giving time for discussion and thinking might be a waste of the lecturer's allocated time. Nonetheless, it has been reported in the literature that giving students sufficient time is an essential element in order to allow them to think and give them the opportunity to talk about their thinking process and make them adept thinkers (Al-qahtani, 1995; McGuinness, 1999; Rodrigues, 2005).

Also, through classroom observations, it was noticed that all the teachers in both years (except one) asked their students many questions while explaining physics problems without allowing opportunities or enough time for thinking. Teachers asked questions and answered the questions themselves. Hence, this may not be helpful in encouraging the students to think of the solution to the physics problems. Also, this does not give the opportunity for students to discuss and participate with the teacher or their classmates while solving physics problems. This research points to the importance of dedicating enough time to give students the opportunity to think about their learning (Rodrigues, 2005; Sahin & Kendir, 2013; Zewdie, 2014). On the contrary, not offering students the opportunity to discuss, think and interact between themselves or their teachers while solving physics problems may influence their understanding of the solution. Dialogue or getting feedback from peers or teachers could facilitate students' understanding of what they want to achieve in order to solve physics problems.

Moreover, when students work together to solve problems through exchanging ideas and viewpoints, this will help their comprehension of the problem (Alrababah, 2017). This is supported by Vygotsky's theory which shows that social interaction plays an important role in the learning process. By not offering the opportunity for students to ask questions or discuss solutions to physics problems, the teacher impedes social interaction. In the absence of interaction between teachers and students or between students themselves, students might not get the opportunity to fully develop their cognitive abilities (Wallace et al., 2012). In this regard, Eun (2019) emphasised that the forms of dialogic interactions used by individuals involved in collaborative activities, affects the individual mental processes.

According to sociocultural theory, through this process of interaction and transformation between people and context, individuals change their responses to establish different kinds of meaning (Stevenson, 2004). Al-Nassar (2011) claims that students derive meaning not only through personal experience but also through social interaction. According to Cole et al. (1978), Vygotsky notes that the functional cultural development of a child can be influenced both socially and individually. This means that this development first takes place at the social level, the "inter-psychological", and progresses within the child to the individual level, "the intra-psychological". Thus, physics lectures are the context for social interaction and, if a teacher gives students the opportunity to participate while explaining the physics problems by helping them to reach a solution or allowing students to discuss among themselves, this would positively impact on their cognitive abilities and their performance in problem-solving. Larkin's (2006) study emphasised that, if students have not been given opportunities to interact with others, this will present a key obstacle to practising or getting feedback from others in relation to their own cognitive processing.

Moreover, Eun (2019) mentioned that when students interact in a joint activity, this leads to psychological development because the less competent students internalise the interactional patterns; the more competent students, in turn, develop as well. The interaction also makes the features of the activity more reflective and conscious.

In the present study, students from both years believed that if they received help and support through discussion and interaction with others, such as students or teachers, this would help them to understand physics problems. This is supported by Whipp, Eckman and Kieboom's (2005) research which suggested that assistance provided to students is not aimed merely at directing and assessing them, but rather at supporting learners through modelling, feedback, direct instruction and questioning to allow them to undertake tasks on their own for which they previously needed support. Hence, as explained by students and teachers from both years and based on classroom observations, the interaction between the teacher and students or among the students themselves was absent. This means that the students were missing significant learning opportunities, as social interaction results in the active processing of information in the individual's mind, which can alter the individual's knowledge and skills (Harskamp & Ding, 2006).

The physics classrooms context at Taif University is an important element because teaching, learning and social interaction should take place while solving physics problems. Also, "knowledge is constructed in the social context of the classroom through language" (Chin, 2006, p.1316). According to Vygotsky's theory, it can be seen that if students do not receive encouragement from their teachers in learning to solve physics problems, or teachers do not make time for students to participate with them, this would impact negatively on the interaction between students and teachers and between students themselves (interpsychological).

It has been reported in the literature (e.g. Allen et al., 2013; Pianta, Hamre, & Allen, 2012) that the interaction between teachers and students in classrooms is connected with students' motivation. Therefore, this affects what students learn at the individual level (intrapsychological) about solving physics problems. In this regard, social interaction in the physics classrooms does not occur while solving physics problems and therefore the understanding of physics problems may not be internalised into the student's mental processes. Furthermore, as a result of the lack of social interaction in the class, students may not acquire the physics concepts which are key to their understanding of physics problems because students' thinking and problem-solving skills are regulated by internalised scientific concepts (Karpov, 2003).

Based on Vygotsky's sociocultural theory, knowledge received from a more able or knowledgeable peer provides support to lower ability students through correcting misunderstandings, filling potential gaps in knowledge, reinforcing the links between new and prior knowledge and enhancing students' problem-solving knowledge and skills (Fawcett & Garton, 2005).

The results of the present study revealed different reasons for the lack of interaction between teachers and students during the explanation of physics problems or among the students themselves, as explained in the section below.

7.2.3.1 Students are accustomed to memorising rather than thinking

Throughout their previous years in school, the students had not acquired sufficient basic knowledge, had not familiarised themselves with expressing their ideas through discussion, and had not been encouraged to take responsibility for their own learning. Rather, it seems that during their previous schooling experience, they had been spoon-fed information, probably due to the vital role the school teacher plays in training the students in memorisation and rote learning, instead of in questioning and discussing. This is consistent with a number of studies (e.g. Alghamdi, 2013; Al-qhatani, 2013; Alshannag et al., 2013) which confirmed that many teachers in Saudi Arabia rely on traditional practices such as assisting students to memorise physics information rather than encouraging them to ask or think. In this context, Alhammad (2015) argued that the traditional methods, which are mainly teacher/textbook-centred and do not incorporate students' participation or contributions, are still prevalent in science education across the Arab world in general and in Saudi Arabia in particular. This idea is supported by Hayes et al. (2015) who conducted research in Bahrain, a country with a similar background to Saudi Arabia, who argued that due to over-reliance on memorisation, students arriving at university face a great shock since they have been used to being "spoon-fed" knowledge and information at school. Therefore, students in this case will not have sufficient strategies to solve different physics problems (Dökme and Ünlü, 2019).

7.2.3.2 Relationships between teachers and students

Another reason for the weak student-teacher interaction while solving physics problems may be related to the teacher's role in relation to his students in the physics lectures. Understanding the nature of the relationship between teachers and students can provide new insights into how physics is taught and learned in relation to physics problem-solving in the university context. The students' interviews from both years, as mentioned in Qualitative Findings Chapter, showed that the students refrained from discussing with their teachers, either because of certain teachers' short tempers or due to the mistreatment of students who asked questions. The teachers may have thought that such questions related to basic knowledge that the students were supposed to have acquired already. The students may have been afraid to ask their teachers due to their potential angry reaction, or from fear of embarrassment in front of their classmates. Also, the teachers did not respect students' questions and did not allow for them to participate. The results indicated that the teacher's power (teacher's authority), because he can threaten the students with grades, can also play a role in preventing students from asking questions in physics lectures. In this context, Scott and Mortimer (2006) stated that "authoritative discourse is closed to the points of view of others, with its direction having been set in advance by the teacher" (p.611). The issue of teacher's power has been discussed by various scholars (e.g. Buzzelli & Johnston, 2001; Cothran & Ennis, 1997; Uitto & Syrjala, 2008); the power of the teacher in the classroom can restrict the freedom of students and creates fear in them. Therefore, students need to have the freedom to think and ask their teachers if they do not understand physics problems rather than being hesitant to use their thinking or ask their teachers, as this was demonstrated by the students' interviews from both years in Chapter Six. Hence, teachers should create a positive atmosphere in order to encourage their students to ask questions and think and teachers should use appropriate teaching methods to foster students' thinking. Teachers should also give students the opportunity to share their ideas to enable them to achieve potential development within their ZPD. Zones of proximal development ought to be created by teaching students using various types of activities (Hedegaard, 1990).

Therefore, the teachers' relationships with their students in this context did not help to create a social environment where the students felt secure about thinking or understanding how to solve physics problems. This finding relates to Harland's (2003) claim that, where such methods are prominent, this hinders the use of more effective practices such as scaffolding in the ZPD. Therefore, it appears that the teacher has an important role in directing students when solving physics problems through creating a social environment that includes interaction, discussion and encouragement as a form of scaffolding. This kind of social interaction creates a secure environment, which allows discussion, participation and thinking about the solution of physics problems, whereby the student becomes an active learner in his/her zone of proximal development. According to the sociocultural theory, through this process of interaction and transformation between people, between the teacher and his or her students or between students themselves, students learn socially to solve physics problems, and individuals change their responses when confronted with physics problems.

Therefore, I argue that providing a suitable and safe learning environment reflects positively on students and creates social interaction and dialogue between students and their teachers and between students themselves in order to access assistance whether from the teacher or from their peers. This assistance could improve students' understanding of the situation or the task (physics problems) (Tharp & Gallimore, 1991). Therefore, teachers should shift from an authoritative mode to a dialogic mode, because the interaction among students and teachers through dialogue gives the opportunity for students to develop their thinking and their ideas. According to Eun (2019, p.21), "the forms of dialogic interactions, discursive practices, and cultural tools employed by people engaged in collaborative activities, will all be reflected in the individual mental processes".

In this regard, Wegerif et al. (2010, p.614) reports that "in dialogues, voices interact in unpredictable ways to produce new perspectives that enable participants to see the topic of the dialogue in a new way", in order to create a safe learning environment to develop students' idea rather than preventing them from interacting with the teacher. In this regard, it was reported in the literature that teachers need to develop students' ideas and comprehension in the classroom through involving students' voices and allowing them to engage in the discussion and that this leads to generative thinking prior to getting the solution (Bungum, Bøe & Henriksen, 2018; Mortimer & Scott, 2003; Wood, Galloway, Sinclair, & Hardy, 2018).

In the following section, the institutional factors impacting on students' learning to solve problems in physics are discussed as these might impact on students' understanding and thinking in relation to problem-solving in physics.

7.2.4 Institutional factors impacting on students' learning of problem-solving in physics

This section relates to the fourth research question with regards to the institutional factors impacting on students' learning of problem-solving in physics. In this section, four important factors are discussed: (1) classroom environment, (2) lack of suitable facilities, (3) university management and Physics Department and (4) syllabus issues.

7.2.4.1 Classroom environment

First, it is worth mentioning that the physics classrooms which I visited had between 45 and 50 students. Sometimes, I noticed that some students did not find space to sit and had to bring a chair with them. Also, the number of students in the preparatory-year classrooms ranged from 50 to 60, whereas, in the first-year it ranged from 40 to 55 students. Moreover, all students had to attend together so there were no small groups in physics lectures.

Among the factors that emerged from the analysis of students' and teachers' interviews from both years were their complaints about the excessive number of students in the class. This issue was believed to prevent students from participating during physics lectures and to prevent teachers from being creative in their lectures. Moreover, teachers from both years confirmed that the huge number of students in the class prevented them from guiding students' thinking while solving physics problems. In this respect, it has been reported in the literature (e.g. Exeter et al. 2010; Nicol & Boyle, 2003; Thomas et al., 2010) that the large class sizes cause students numerous challenges that prevent them from engaging with the course content and hinder the teacher's ability to have discussions with the students. Therefore, students seemed not to have the opportunity to get assistance with their performance, such as feedback and questioning from their teachers.

Lidz and Gindis (2003) cite Vygotsky in asserting that the ZPD was affected by the student's capacity to collaborate with experts in order to improve his or her performance beyond his or her initial level without assistance. However, it can be argued that large class sizes reduce the chance for students to benefit from their participation or get more attention from the teacher or get any assistance with solving physics problems. Therefore, students, in this case, could be considered as inactive learners in their zone of proximal development, which might make them over-dependent on their teachers to receive physics information. This is because, with the large number of students, teachers seem to rely on traditional practices such as assisting students to memorise physics information rather than encouraging them to ask or think. It was reported in the literature (e.g. Albadi, Harkins, & O'Toole, 2018; Monks & Schmidt, 2010) that large class sizes prompt teachers to use less effective teaching methods, which reflects negatively on students' learning.

Regarding the classroom environment, the analysis of students' interviews from both years, as shown in Chapter Six, revealed that some students were wasting time and talking to each other during the physics lecture, which, therefore, affected the teacher's performance and eventually the students' understanding.

Also, the classroom observation findings from both years showed that students often arrived late, which caused the teacher to interrupt the explanations several times. Moreover, it was noticed that a preparatory-year student made a phone call for two minutes during the teacher's explanation and that three students were using their phones to watch YouTube videos or play games. These behaviours could be related to the class size as teachers may not have the ability to control their classes; this, eventually, would have a negative effect on students' understanding and thinking (Albadi et al., 2018; Monks & Schmidt, 2010).

The above issues indicate that students were not active agents during their learning within the classroom context and did not pay attention to their learning in the physics lecture in order to understand how to solve physics problems. Panofsky (2003) claims that through activities certain students can demonstrate a strong sense of agency while others may perceive themselves as weak and inadequate learning agents. The latter may even exercise agency by rejecting school activities through active antagonistic behaviour or passive disinterest.

Therefore, as mentioned earlier in this chapter, the lack of students' readiness for physics lectures could be related to factors such as the lack of interaction between teachers and students, or among students themselves, during the explanations of physics problems, the lack of student interest in the physics lectures, the teachers' reliance on traditional methods and the great number of students inside the classes which, therefore, depend on memorisation and rote learning. Therefore, teachers should work to help their students be active learners while solving physics problems, and the university should reduce the number of students inside the classroom by, for example, creating additional classes. The next section discusses findings about the importance of suitable facilities in helping students to learn and understand in physics lectures.

7.2.4.2 Facilities

The interview findings from students of both years and from one preparatory-year teacher pointed to the importance of suitable facilities in helping students to learn and understand how to solve physics problems. Such facilities include, for example, suitable instructional tools to facilitate physics learning, classroom equipment and technological tools, or physics laboratory with adequate equipment. This finding is consistent with what has been reported in the literature (e.g. Alshammari, 2014; Ferreira, Baptista, & Arroio, 2013; Harlen, 1999) that using instructional tools is useful for teachers and students and that such tools help students to build their scientific knowledge and make their learning in science quicker and easier.

According to Bruner, Rieber, Minick and Carton (1987), Vygotsky argued that the role of instructional tools is to build students' knowledge and that these tools act as mediators to solve problems. Moreover, "Vygotsky himself primarily emphasized symbolic tools-mediators appropriated by children in the context of particular sociocultural activities, the most important of which he considered to be formal education" (Kozulin et al., 2003, p.17). Therefore, instructional tools play an important role to help students during their learning.

Also, based on classroom observations, it was noticed that some classes were not adequately prepared for students in terms of chairs and whiteboards, as shown by the pictures taken during classroom observations in both years, as mentioned earlier, in Chapter Six. With regard to the preparation of the classroom before lectures, when I distributed the questionnaires to the students to collect quantitative data, the students, their teacher and I were surprised that the door of the classroom required fingerprint verification and we could not enter, forcing us to spend about 15 minutes of lecture time searching for another available classroom.

Therefore, the preparation of the classroom before the lecture is important because, if it is not ready at the start of the lecture, this will be at the expense of the lecture time. This would tend to make the teacher rush in his explanations without giving his students the opportunity to discuss or think about ways to solve physics problems. The students believed that providing suitable facilities, such as instructional tools to facilitate physics learning, classroom equipment and technological tools, was a factor affecting their learning; this would make the physics lesson more enjoyable and promote their thinking and creativity while solving physics problems.

It has been suggested in the literature (e.g. Al-sughayer, 2007; Orr & Klein, 1991; Owu-Ewie, 2008) that the physical classroom environment plays an important role in promoting or hindering thinking skills. Therefore, it seems that the context (classroom environment) did not provide the opportunity for students to facilitate their understanding and their thinking in physics. Moreover, the students from both years complained about the lack of facilities and seemed to perceive themselves as weak and inadequate learning agents (Panofsky, 2003), because they believed that that they could not think or learn due to the weakness of the facilities available to them. For example, a first-year student wondered how students could be asked to think and interact with others while solving physics problems when classrooms were not prepared. Also, students from both years and a preparatory-year teacher emphasised that the classrooms did not allow them to create an environment to discuss or implement cooperative learning strategies in order to develop thinking in physics lectures because the chairs could not be moved. Therefore, students missed out on important learning opportunities to discuss with their peers, share knowledge and exchange experiences when solving physics problems (Reid & Yang, 2002).

On the other hand, one of the first-year student seemed to have overcome the obstacles he faced while learning to solve physics problems. For example, he explained that when he did not comprehend part of a physics problem, he looked for its solution on line, as there was no appropriate library that met his needs. This suggests that this student overcame the lack of facilities through looking for suitable resources from the wider context instead of relying on the current facilities within the university context. Therefore, he seemed to have a strong sense of agency which guided and motivated him to search for appropriate information in order to understand physics problems. In this regard, Vygotsky argued that the context is not an entire entity that has the same impact on every learner, but actually depends on the age and the mental capacity of the learner (Veer, 2007).

As for the teachers, concerning the lack of suitable facilities, it was interesting to note that only one preparatory-year teacher referred to this point, whereas the rest of the teachers did not mention this issue at all; this may be because all the teachers who were interviewed were non-Saudis, except one. Thus, they might not want to be critical about the facilities provided, fearing to lose their position in the university. Nonetheless, they were frequently informed that their data would be treated confidentially. The next section discusses the findings about the impact of the university management and the Physics Department on student learning and teacher performance.

7.2.4.3 Impact of the university management and the Physics Department on student learning and teacher performance

The data analysis of the interviews of teachers from both years highlighted the influence of the university management and the Physics Department on teaching. Teachers from both years emphasised the role of the university and the Physics Department administration in terms of its influence on the teachers and, in turn, on students. They complained about the department's administration because they were asked to teach courses outside their areas of specialisation, due to the lack of faculty members and, while they felt compelled to do it, they believed that it was detrimental to students' learning. It has been suggested in the literature (e.g. Poland, Colburn, & Long, 2017; Sanders, Borko & Lockard, 1993) that, if teachers teach an unfamiliar science area, they occasionally act as novice teachers, as specialisation is a tool that helps reduce workload and allows teachers to improve their teaching. Thus, the university management and the Physics Department should give more consideration to the teachers by not requiring them to teach any course out of their area of specialization. As a result, if teachers establish connections with their students in a subject they have mastered, they would be more likely to rouse their students' interest and meet their needs and, in turn, act as change agents in the physics classroom (Moore, 2008).

Another factor, noted by a first-year teacher, was the importance of the administration in meeting teachers' needs such as providing training in problem-solving skills, thinking skills and teaching methods, because he believed that this could positively affect students' understanding in physics. This finding is consistent with what has been reported in the literature about the role of administrators and education policy makers to develop and encourage professional development in order to improve the quality of teachers (e.g. Abo Watfah, 2002; Alghamdi, 2012; Desimone, Smith, & Ueno, 2006; Qablan et al., 2015; Scribner, 1999). This was particularly important for all the participating teachers of this study who, as mentioned earlier in this chapter, were specialists in the sciences but had not received any formal training, or received insufficient training, in the pedagogy of teaching and learning physics.

Another issue that should be considered here is related to the influence of the university management on assessment design. For example, the findings of interviews with teachers from both years suggested that tests with multiple choice questions (MCQs) indirectly affected students' learning and their way of dealing with problem-solving. According to the participants, such tests are problematic and do not support students' thinking and problem-solving skills, because they make students accustomed to memorising rather than thinking. Moreover, according to a preparatory-year teacher, the vast majority of students concentrate during the examination on MCQs, which count for 70% of the score, and ignore other parts of the examination (physics problems) which count for 30% of the total grade.

This finding is consistent with a number of studies which mentioned that MCQs encourage students to memorise and do not promote high level cognitive processes (Airasian, 1994; Scouller, 1998 cited in Nicol, 2007). Therefore, as mentioned by teachers from both years, “the university policy is to design the test based on multiple choices” and teachers are not allowed to change this kind of test, because their voices do not seem to be taken into account. This finding concurs with Mansory (2016), who conducted research in Saudi Arabia and emphasised that university teachers did not have a role in summative assessment unless they were involved in the assessment committee. He also found that most teachers expressed the desire to have their voices heard and to be more involved.

Hence, it appears that the university context, such as regulations and rules of the university regarding test design, might encourage students not to pay attention or interact with the teacher or between themselves to understand or learn how to solve physics problems. This is because, in this case, students know that the examination will contain of a large percentage of MCQs. Thus, students seemed to perceive themselves as having a weak motivation to learn, which limited their power to learn and did not allow them to follow the steps of problem-solving. Therefore, teachers need to have their voices heard and be involved in the assessment process, because they have concerns about this kind of examination.

The syllabus taught in the preparatory-year and the first-year and its relationship with students' understanding of problem-solving in physics is discussed in the next section.

7.2.4.4 Syllabus issues

In this section, the summarised booklets, *the thinking and learning skills syllabus* and integrating thinking skills within the syllabus are discussed.

The data analysis of interviews of all students and teachers demonstrate that students are satisfied with the summarised booklets used in both years and find them easy to understand. It is worth mentioning that in the Saudi context, it is common for teachers to summarise their courses into a short booklet (summarised booklets) and make it available for students at the printing centre in the university. Students and teachers also mentioned some reasons for not using a physics book and for using summarised booklets instead, such as, for example, the difficulty of the language used in text book and its high price. Indeed, because the book is written in English, the teachers do not refer to it. These views about the summarised booklets are consistent with Alazemi (2017) who found that, in Kuwait, university students are satisfied with summarised booklets because academic books are expensive and difficult to understand.

However, some students and teachers from both years have critical views about such booklets because they do not include images that help students grasp the physics problems. These summarised booklets, therefore, require more clarity in terms of how to solve mechanics problems and are not helping students to be familiar with a variety of physics problems.

In light of such criticism from some participants, I argue that the students' reliance on these summarised booklets might provide them with the minimum required information about physics problems, which might also lead to reducing the opportunity for students to learn. This is because, if students refer to the physics textbooks, they might expand their knowledge about physics phenomena and gain a better understanding rather than relying on the limited information contained in the summarised booklets. As mentioned earlier, in Chapter Six, teachers from both years play an important role in encouraging students not to refer to the physics books. Indeed, because every syllabus has main references and additional references, if the teachers from both years accustom their students to not referring to the main references or the additional references and restrict students to learning only from the few pages of the summarised booklets, this might prevent the students benefitting from the extra explanations and the variety of examples of physics problems presented in the textbooks compared to the summarised booklets. These extra explanations and the variety of examples might help students to enhance their understanding of physics problems. Therefore, if the teachers' practices with their students do not encourage students to access other references and encourage them to merely rely on the summarised booklets, this could limit students' opportunity to expand their physics knowledge.

Also, the data addressed the issue of *the thinking and learning skills* syllabus in terms of its importance and its role in preparing students in problem-solving. Based on the findings obtained from students of both years, it appears that few students (one preparatory-year and one first-year student) had positive views about the *thinking and learning skills* syllabus. For example, a preparatory-year student, as presented in Chapter Six, reported that he benefitted from this syllabus, especially by showing him how to deal with physics problems. On the other hand, other students from both years (three preparatory-year and two first-year students) held negative views about that syllabus. For example, a preparatory-year student expressed the view that the syllabus was useless and felt it was a waste of his time. Also, a first-year student saw that studying thinking skills in that syllabus was not important and irrelevant to his specialisation.

However, the above differences in students' perceptions about the importance of the thinking and learning skills syllabus might be due to the fact that some students realised the importance of thinking skills and used them when solving physics problems while others did not see their importance, because students with negative views about this syllabus saw themselves as having the ability to solve physics problems without using this syllabus.

Therefore, the difference in the perceived power of change among students might be related to the extent of the students' awareness of the importance of using thinking skills in their learning while solving physics problems. This is because some students from both years saw that learning thinking skills, as presented in the *thinking and learning skills* module, was useless and that they did not benefit from this syllabus in terms of thinking skills. This is in line with the findings of studies conducted in Saudi universities which found that students lacked thinking and critical thinking skills (e.g. Allamnakrah, 2013; Alwehaibi, 2012).

Regarding integrating thinking skills within the physics syllabus, some teachers and students from both years claimed that thinking skills should be included within the physics syllabus because this could positively affect students' understanding of physics problems. These findings are consistent with other studies (e.g. Burke & Williams, 2008; Dewey & Bento, 2009) which argued that integrating thinking skills within the subject, through an infusion approach, plays an important role in improving students' thinking. Therefore, if thinking skills are integrated within the physics syllabus, this might encourage teachers to move beyond the traditional teaching methods and use methods based on thinking skills, such as using problem-solving skills, reasoning and enquiry. Thus, using thinking skills in their teaching might allow teachers to guide their students' thinking while solving physics problems. In this respect, Beyer (2008b) argues that the inclusion of thinking skills within the taught material not only enhances the learning of the subject matter, but also the level of students' thinking. Moreover, according to sociocultural principles, teaching thinking as part of the physics syllabus might be considered as an assisted performance to help students and guide their thinking in their learning of physics.

The following section discusses how sociocultural factors impact on students' learning of problem-solving in physics.

7.2.5 Sociocultural factors impacting on students' learning of problem-solving in physics

This section relates to the fifth research question with regards to the sociocultural factors impacting on students' learning of problem-solving in physics. In this section, two important factors are discussed: (1) social and cultural aspects, (2) language issues.

7.2.5.1 Social and cultural aspects

As explained in the Qualitative Findings Chapter, interviews with four teachers from both years and seven students in the first-year showed that the family in general and parents in particular intervened in their children's choice of physics specialisation, which may have contradicted their child's own wishes. As a result, this may have led some students to study physics without wanting to, which was reflected in their understanding of physics. Hence, the family context, in this study, did not allow students to make choices about their studies; students seemed to be forced, as reported in this study's findings, which means that there was absence of choice.

However, it has been reported in the literature that students choose what they want to study but that their decisions are guided and directed by their family. For example, Oon and Subramaniam (2013) explained that the decision-making process of physics students can be influenced in multiple ways by parents and classmates. Also, Van de Werfhorst, Sullivan and Cheung (2003) note that the social, economic and cultural position and capital of parents can guide children in their decisions and serve as a reference point when making their own individual decisions. Forcing students to choose a specific specialisation is an indication that students' voices are ignored, which might influence their learning in a negative way, as reported in this study's findings.

For example, in the classroom observations, as mentioned in Chapter Six some first-year students did not seem to care about the lectures, especially those who said that they were forced to study physics; some were sleeping, others chatted with their classmates about topics irrelevant to physics while others were occupied with their mobile phones. Therefore, forcing students to study physics might negatively influence their learning, and lead to a lack of a sense of agency. Students might not see themselves as agents of change or as active learners. As presented in the Qualitative Chapter, some first-year students during the interviews reported that they had a weak desire to study and understand physics and that they had been forced by their families or community to study physics without conviction. This could have been because their parents saw the importance of employment after graduation and because their parents or families believed that choosing scientific specialities such as physics would help students find a job more easily than choosing literary disciplines.

According to Jurdak (2016), "the learner's agency entails recognition that learning is contingent on the learner's motivation, consciousness, actions, and interactions with the social, cultural, and physical environment in which learning is taking place" (p.176). However, I did not find any interaction between those students (passive learners) and their teachers and they did not seem to pay attention to understanding physics problems. The interviews with first-year students and teachers from both years confirmed the argument that students did not care to understand, think about or solve physics problems because they felt forced to study physics by their families. Kattanah (2010) stated that, if students are not forced to choose a specific specialization, and they are given a chance to choose an appropriate specialization based on their own interest, this would enhance their ability to continue their academic career successfully. Therefore, students need to be interested in studying physics and not be forced into studying it because, as pointed by Kitchen, Sonnert and Sadler (2018), students' interest plays a significant role in academic achievement and learning.

In this regard, it is emphasised that students will learn physics effectively if they are interested in it (Badri, Al Mazroui, Al Rashedi, & Yang, 2016).

In the present study, the interview findings with first-year students and teachers from both years also highlighted that society played a major role in influencing the students to choose this specialization. For example, preparatory-year and first-year students emphasised that society, their family and parents believed that scientific specialisations (e.g. physics, chemistry, engineering etc.) were better than the humanities or the social sciences (e.g. administrative, financial sciences, arts) in terms of employment. This argument is consistent with Alzahrani's (2010) study which investigated Saudi higher education outcomes; he found that students who graduated from the humanities and the social sciences found it difficult to get a job, as such specialisations were not suited to the needs of the labour market. Therefore, families forcing students because of employment issues into choosing unwanted specialities at the expense of their personal choices might reflect negatively on their understanding of physics. In addition, the aspect of searching for a specialization that is required in the labour market for the purpose of job security is one of the social aspects that affects the students' choice of a specialty that they do not like. As a result, if students do not want to study physics, this may have a negative impact on their learning in general and their understanding of physics problems in particular, thus leading to wasting time and effort.

However, the qualitative results show that the employment aspect is important in raising the students' interest in learning physics. Recently, the recruitment of university graduates has not been as efficient as it used to be years ago. In this respect, Aloeashiq (2014) mentioned that unemployment rates among young people and graduates are particularly high and that university graduates, including postgraduates, represent the largest proportion of the unemployed (49%). New graduates may only obtain a job many years after graduation, especially in the case of physics graduates willing to work in the domain of teaching. Therefore, for the students, the presence of a growing number of unemployed graduates in the Saudi context, including friends or relatives, may reduce the number of students willing to learn physics in the future. In this respect, Tee Oon and Subramaniam (2010) highlight that students may come to realise that there is not a high demand for physics graduates in the job market and potentially avoid this specialisation. Thus, it can be argued that students are aware of the growing number of unemployed physics graduates in the Saudi context, which affect their learning behaviours, motivation and interest in learning physics.

Moreover, based on students’ interviews in both years, it appears that the social environment surrounding the students, especially the family background and the culture of the community where they live, might accustom them to not caring about their learning in general and about learning physics in particular. One first-year student, as demonstrated by the data, seemed to have his beliefs towards learning influenced by the place where he lived insofar as most people from his community were Bedouin villagers who had no interest. This relates to Alhammad’s (2015, p.124) statement that “the articulation of knowledge depends upon what students have accumulated from the cultural values and environment in which they live”.

Also, the interview with a preparatory-year student showed that he had come to the university with negative beliefs towards physics that were created by his classmates at school and by his parents. For example, among these beliefs was the idea that physics is very difficult to understand and that it requires a high level of thinking skills. Therefore, when he came to university, he was not ready to engage in thinking and solving physics problems because of his preconceived negative beliefs constructed through his parents and the school.

In the KSA, students join universities from different regions in Saudi Arabia with different social backgrounds and different ways of thinking but with the same educational background. For instance, some students come from urban or rural areas, and therefore, certain social and cultural factors might impact on their learning in physics. This has been reported in the literature; for example, Sahin (2010) mentioned that research had demonstrated that students had a limited understanding of physics upon entry to a course, along with predetermined attitudes, beliefs and expectations. These preconceived expectations and beliefs impact on their learning in introductory physics courses and how they interpret the knowledge gained in the physics classroom. Moreover, when students enter an introductory physics course, they bring with them a set of beliefs regarding physics, which is often vaguely based on incorrect empirical evidence (Martín-Blas et al., 2010). Therefore, the students acquire beliefs through their interactions with the sociocultural environment and this interaction has an influence on their identity formation as learners of physics. This, in turn, influences their practices and in problem-solving both in the preparatory-year and the first-year. As a result, the students might see themselves as unable to solve physics problems or as ill-prepared to study physics. Mansour (2010) points out that the process of acquiring and interpreting new knowledge and the way in which learners select and organise their tasks are all impacted by personal beliefs.

Furthermore, first-year students mentioned that the family, friends and colleagues and the society surrounding students affected their beliefs about physics. For example, students do not like mathematics and this notion is built through friends, schools and the university community; therefore, when they deal with mechanics problems that contain equations and figures, they have a fear and a belief that they will not reach the solution correctly, which also acts as a barrier to understanding physics. It can be seen that this barrier to understanding physics has been shaped over time by the society where students live and interact, and then remained with the student at university. This is supported by Pimthong (2015) who highlights that learning is influenced by the immediate classroom context and by society at large. Therefore, the psychological tools such as the beliefs and perceptions of students might be developed in the school context and later on influence their learning when they move on to the university stage. This also relates to Perkins et al. (2005) who concluded that students who hold positive beliefs when they come into a course are more likely to have high learning gains.

In the following section, language issues will be discussed as these might impact on students' understanding and thinking in relation to understanding and solving physics problems.

7.2.5.2 Language issues

The data from students' interviews and a classroom observation highlighted the impact of teachers' Arabic dialects/accents and of the use of English as a medium of instruction. Also, the data pointed to the importance of the use of specific physics technical language. All these issues are discussed in this section.

The findings from interviews with students of both years revealed that teachers' Arabic dialects influenced students' understanding and thinking when dealing with mechanics problems in physics lectures. The data strongly suggest that students felt they could not follow the teacher because of their dialect or accent. Students mentioned that, while solving physics problems, teachers' explanations were sometimes incomprehensible to them. According to Gluszek and Dovidio (2010): "If listeners assume that accents interfere with comprehension, they may readily come to believe that they cannot understand accented speakers, even when they do in fact understand the accented speech" (p.224).

Moreover, mediation is one of the key ideas in Vygotsky's (as cited in Cole et al., 1978) theory, and it can be seen as playing an important role in understanding human activities. Wertsch (1991) argued: ''human action typically employs 'mediational means' such as tools and language, and that these mediational means shape the action in essential ways" (p.12). In the same vein, "the action, therefore, is carried out by the individual in a concrete situation with the mediational means involved" (Mansour, 2010, p.530). In the current study, the difficulty of students' understanding of physics problems was compounded by their teachers' dialects, which can be considered as mediating tools.

It is worth remembering that the physics lecturers came from different parts of the Arab world and spoke in different accents and, therefore, the students' focus may have been on trying to understand the teacher's dialect instead of understanding the mechanics problem. As mentioned in the Qualitative Findings Chapter, this might cause an additional cognitive burden for students. A first-year student, for example, mentioned that he felt he had to keep thinking about the teacher's pronunciation rather than focussing on understanding the mechanics problem. Another first-year student also mentioned that his teacher's dialect caused difficulty and that, therefore, he could not participate with his teacher, as mentioned in the qualitative findings. Thus, this might limit the students' engagement and interaction with their teachers during the explanation of physics problems.

Furthermore, if students had the freedom to think and ask their teachers if they did not understand physics problems, rather than being afraid, this might reduce the burden of learning physics and the understanding of teachers' dialect. It seems that on Vygotsky's "inter-psychological level", the students did not follow their teachers in thinking about solving physics problems because they had a cognitive burden related to the understanding of physics and, in addition, a linguistic burden related to the teachers' dialects and pronunciation differences. This, in turn, might impact on students' understanding of physics problem-solving.

Furthermore, students and teachers from both years referred to the English language and how it affected their understanding of physics problems. They expressed the view that English was a challenging aspect because problems were written in English in the summarised booklets or on the whiteboard, as well as the physics equations, physics signs and the instructions for physics problems. In addition to their difficulties in understanding physics, this caused another burden. Therefore, it seems that the cognitive functions (e.g. thinking in understanding physics problems) of students were mediated by the English language used in physics. In this respect, Karpov (2003) cites Vygotsky' theory in asserting that higher cognitive processes are mediated by psychological tools including language, signs, and symbols, which are all products of our society as humans and assimilated by children though interaction with adults or other more experienced children.

Also, in the case of a first-year student, the interview findings strongly suggest that the teachers' use of English words impacted on students' understanding of physics problems and caused confusion. These findings are consistent with Troudi (2009) who argued that learning in a foreign language represents a burden for many students and can impede their knowledge acquisition. Thus, this burden might make students inactive learners in their zone of proximal development as learning in a foreign language often exerts an additional cognitive load on students' intellectual resources, as close attention needs to be paid to the language in which the content is being taught, in addition to the content itself (Afitska, 2015).

Furthermore, it can be seen that English played a role in the students' understanding of the symbols used in physics, which could affect their understanding when dealing with physics problems. For example, students were confused between the symbol "W" for *weight* and *work*, as reported by a preparatory-year teacher and a first-year student. This finding is consistent with

Bower and Ellerton (2007) who point out that scientists and mathematicians express subject-specific meanings through particular words and symbols, which may have no equivalent in a student's own language, thus causing confusion for learners. This confusion with regard to the symbols of physics might relate to the low level of English language proficiency among students, which is a major problem in Saudi Arabia across all stages of the education system (Alhmadi, 2014). According to Albadi et al. (2018, p.1), "recent research in science education for learners whose first language is Arabic suggests that learning in the mother tongue can reduce learner misconceptions". Also, it is worth bearing in mind that, until university, Arabic is used as the only medium of instruction, while at university the recent language policy changes have resulted in using English as the medium of instruction for most Science, Technology, Engineering and Mathematics (STEM) subjects. In addition, the course books used at university are in English and employ a very different terminology, which differs from the physics books used in secondary education. In this regard, students need to improve their English language skills before starting university (Hayes et al., 2015).

Furthermore, it was found in a first-year classroom observation that, while the teacher was explaining the concept of "force analysis", he used the symbols in Arabic and wrote them on the whiteboard in English. The confusion this caused the students seemed to be mediated by the teaching process. Indeed, as mentioned in the qualitative findings, teachers believed that teaching the physics symbols in Arabic language was the best way to ease students' understanding, whereas writing in English on the whiteboard was a way to accustom students to using them later on in their studies. In this regard, Mansour (2009) argued that "teachers' beliefs about learning science refer to their conceptions of the process of learning science, what behaviours and mental activities are involved on the part of the learner, and what constitutes appropriate and prototypical learning activities" (p.28). Thus, in the current study, teachers' perspectives about the teaching process were shaped by the demands and nature of physics problems and the level of students in terms of physics subject knowledge.

Also, the interview findings from students of both years and a preparatory-year teacher revealed the importance of the language in which physics problems were expressed in helping or hindering students' understanding. Thus, the difficulties students faced when solving physics problems were mediated by the language used. This is because the language used in physics problems can be considered as a psychological tool which helps or hinders students' understanding of physics problems.

In this respect, according to Brookes (2006), physics uses an extensive vocabulary with many words that have a technical meaning very different from common usage. Students are expected to retain the unfamiliar technical meanings, which can be increasingly challenging if they contrast with common usage. Thus, this difficulty might limit students' understanding and they might face difficulties understanding and interpreting the language used in physics problems. In this context, "this misinterpretation of language leads students to confusion that is sometimes classified as a misconception" (Itza-Ortiz, Sanjay Rebello, Zollman, & Rodriguez-Achach, 2003, p.330). So, if students have a confusion about understanding physics concepts and do not have clear meanings for these concepts, this would affect their ability to solve physics problems. This claim has been reported widely in the literature (e.g. Alshaya, 2014; Hestenes et al., 1992; Kim & Pak, 2002; Ültay 2017), that when students understand more conceptually, this will reflect positively to improve their ability to interpret and to be successful in problem-solving in physics. Therefore, this raises the importance of the language of instruction, because the language used in the teaching and learning of physics might constitute a difficulty for students and be related to their misunderstanding of scientific terminology (Brookes, 2006; Setyani, Cari, Suparmi & Handhika, 2017). So, "physics instructors should be more cognizant of the use of language and the alternative meanings of physics terminology that their students bring with them to class" (Itza-Ortiz et al., 2003, p.336).

7.3 Summary of the chapter

This chapter discussed the main findings of this study in light of the literature in general and in line with the sociocultural theory in particular. The next chapter will conclude the present study.

Chapter Eight: Conclusion

8.1 Introduction

This chapter concludes the thesis with an overview of the study. Then, the chapter presents the contributions of this study to knowledge and to methodology. Also, the chapter highlights the limitations of this study, and highlights the implications of this study for university management, physics teachers and students. Moreover, it makes a number of suggestions for further research. Finally, the chapter concludes the thesis with final remarks.

8.2 Overview of the study

This study was conducted to investigate students' problem-solving in physics in higher education in Saudi Arabia from university teachers' and students' perspectives. In order to achieve this, the FCI and MBT questionnaires were administered, followed by interviews, think aloud protocols and classroom observations to gain a deeper understanding of students' problem-solving in physics using qualitative methods. Thus, this study addressed the following research questions:

1. To what extent does the level of Taif University preparatory-year and first-year students' understanding of the basic concepts in mechanics allow them to solve physics problems adequately?
2. What strategies are used by Taif University preparatory-year and first-year students when they deal with physics problems, and why do they use such strategies?
3. What are students' and teachers' perceptions about physics teaching methods?
4. What are students' and teachers' perceptions of the institutional factors impacting on students' learning of problem-solving in physics?
5. What are students' and teachers' perceptions of the sociocultural factors impacting on students' learning of problem-solving in physics?

The next section provides answers to the above research questions.

8.3 Answering the research questions:

8.3.1 Students' understanding of basic concepts to solve physics problems

This section addresses the first research question: "To what extent does the level of Taif University preparatory-year and first-year students' understanding of the basic concepts in mechanics allow them to solve physics problems adequately?" The quantitative findings showed that students' results on the FCI and its categories (i.e. kinematics, first law, second law, third law, superposition principle and kind of forces) were below 60%. Also, for the MBT questionnaire and its categories (i.e. kinematics, general principles and specific forces) the results were below 60%, as shown in Table 5.1 and Table 5.2. Moreover, the FCI and MBT results of the 21 students who were interviewed were below 60%, as shown in Table 5.12. Moreover, the correlation between students' understanding of the basic concepts in mechanics and their problem-solving skills in mechanics was found to be a medium-sized one, and statistically significant.

8.3.2 Students' problem-solving strategies

This section addresses the second research question: "What strategies are used by Taif University preparatory-year and first-year students when they deal with physics problems, and why do they use such strategies?" The data analysis of the interviews with students and teachers and think aloud protocols with students revealed that students from neither year seemed to use the steps of problem-solving to help them understand the problem; rather, they focused on finding the data given. They often found difficulty in understanding the problem which was given to them during the think aloud protocols.

In addition, the data showed that students from neither year could not imagine and conceive the problem, which caused them difficulties in terms of "understanding the problem". During the interviews, all the teachers indicated that the students had difficulties in comprehending physics problems from different aspects. For example, teachers explained that students seemed to find difficulties imagining the problem and perceiving the dimensions of the problem in order to understand it. Also, from think aloud protocols, the students did not pay enough attention to understanding the physics problems as they immediately jumped to thinking about the physics laws and the substitution rather than understanding the problem. This suggests that they should be trained and guided in order to understand physics problems.

The think aloud protocols with students from both years also showed that students lacked the skills of “planning” when solving a problem and did not seem to understand how to plan in order to reach the solution to a physics problem. Also, from the interviews, all teachers indicated that the students had no clear methods in the solving process. Regarding the step of “carrying out the plan”, the data from the think aloud protocols confirmed that there was no clear indication that students were carrying out a plan to reach the solution of a problem. Furthermore, with respect to the “looking back” step, all student participants, when asked to solve the mechanics problem during the think aloud protocol, did not demonstrate that they implemented this step while solving the problem, except one first-year student.

Moreover, the results obtained from students’ interviews from both years showed that more than half the participants did not implement the steps of problem-solving when dealing with physics problems in general and mechanics problems in particular. Student participants from both years gave reasons preventing them from implementing the steps of problem-solving in physics. These reasons relate to understanding the physics problem, understanding the physics syllabus and the difficulty of physics problems. All the teachers agreed that the students did not follow any systematic procedure while dealing with physics problems. Also, students in this study did not seem to have an adequate understanding of the steps of problem-solving when they were asked to solve a physics problem during the think aloud protocols.

The analysis of the interviews and classroom observations revealed that the lack of basic physics knowledge acquired from school seemed to reflect negatively on students’ understanding of physics and in their approach to solving physics problems. In this respect, the interview findings from the preparatory-year student and preparatory-year teacher, revealed that the university teachers did not pay enough attention to explaining certain mechanics problems as they believed that students had the necessary basic physics knowledge acquired from school relevant to these problems. Therefore, this was reflected negatively in students’ understanding of physics. While their schools should give them basic physics knowledge which enables them to understand physics, they found that the school had accustomed them to memorisation rather than thinking in solving physics problems. Some teachers mentioned that the matter of continuous evaluation in school was catastrophic for the students because they succeeded without any mastery, which led to a weakening of their basic scientific knowledge and negatively influenced their ability to solve physics problems.

Furthermore, the data collected from teachers in both years revealed the preparatory-year students' lack of basic physics knowledge and the first-year students' lack of basic mechanics knowledge. The data also showed the students' lack of basic physics knowledge acquired from university as teachers mentioned that the academic standards of physics students over recent years had been weaker than in the past. Interestingly, this lack of basic knowledge seemed to be reflected in the level of pre-service teachers in school and, in turn, in the students' own level.

Also, students from both years and two preparatory teachers referred to the students' lack of basic physics conceptual understanding as causing their confusion in understanding physics concepts. Furthermore, the analysis of interviews of students from both years revealed another important aspect regarding the students' lack of basic knowledge. The findings suggest that most difficulties facing students in problem-solving were caused by a lack of basic mathematical knowledge. In addition, students and teachers believed that having basic mathematical knowledge facilitated solving physics problems. Moreover, all teachers confirmed that their students lacked basic mathematical knowledge and that the obstacles students faced were related to their lack of basic mathematical knowledge. A classroom observation confirmed that students in the preparatory-year made basic mathematical errors, such as in conversion from metres to centimetres or from multiplication to division.

8.3.3 Physics teaching methods

This section addresses the third research question: "What are students' and teachers' perceptions about physics teaching methods?" The interview findings showed that all students and teachers clearly held different perspectives about the importance and the role of teaching methods in helping students understand and deal with physics problems in general and mechanics problems in particular. Furthermore, the interview findings suggest that all students from both years expressed a set of concerns about the teaching methods used in the explanation of physics problems. These concerns relate to the absence of diversity in teaching methods (teachers from both years adopt a lecturing approach in delivering the information to the students), to how teaching methods affect students' understanding and their thinking and how certain teaching methods encourage students to rely on memorisation. Also, teachers from both years highlighted reasons preventing them from using more varied methods in teaching physics problems, such as the lack of time and the length of the syllabus. Moreover, the findings from classroom observations showed that teachers encouraged students to memorise and that certain teachers did not provide students with the opportunity to participate when solving mechanics problems.

While conducting classroom observations, it was noticed that all the teachers questioned their students while solving mechanics problems; for example, they asked: “What is the unknown?” “What is the given part?” “What is the relation between the data and the missing part?” However, it was also noticed that the teachers asked these questions without giving students the opportunity to think about possible answers so that the teachers often answered the questions themselves. The exception to this was in one classroom observation of the preparatory-year where the teacher aided comprehension of the mechanics problem with his students by using a graph to clarify the requirements of the problem. Also, he checked the students' understanding using certain questions, such as “What is the unknown in the physics problem?” or “What are the data in this problem?”.

Furthermore, in all the classrooms observed, teachers did not focus on the “planning” step except in one preparatory-year lesson where the teacher explained how to devise a plan to solve problems. Regarding the “looking back” step of problem-solving, based on classroom observations, this step was not apparent in the teachers' explanations of the solution of the mechanics problems. This comes with the exception of a preparatory-year classroom where the only evaluation aspect used by the teacher was checking that the measuring units used in the solution made sense, which he discussed with the students. Also, based on the classroom observations, it was found that teachers did not give their students the opportunity to practise and implement the steps of problem-solving.

Also, the interviews revealed that preparatory-year teachers and students from both years showed how the teaching methods used with the students while studying physics in secondary school had influenced the preparatory-year and first-year students in becoming accustomed to memorisation instead of thinking. Moreover, based on the interviews with students and teachers, the findings indicated that interaction during physics lectures between teachers and students or among the students themselves was almost inexistent. Students indicated some reasons which prevented them interacting with teachers during lectures, such as the teacher's power, the teacher's anger and the fact that they were not accustomed to discussing or interacting with their teachers because they feared to ask questions. Moreover, students' interviews in both years confirmed the importance of a friendly relationship between the teacher and the students during the lecture as this would make students feel comfortable when asking questions, interacting with their teachers or when thinking. Also, according to the classroom observations, it was noted that teachers did not use positive words to encourage their students.

Furthermore, teachers from both years confirmed the absence of students' participation and interaction during the lecture. This was confirmed by classroom observations as no interaction or discussion with the students was noted when solving physics problems except in one classroom observation in the preparatory-year.

8.3.4 Institutional factors affecting students' learning of problem-solving in physics

This section addresses the fourth research question: "What are students' and teachers' perceptions of the institutional factors impacting on students' learning of problem-solving in physics?" The interviews with students and teachers from both years and classroom observations revealed that a number of factors affected students' learning of problem-solving in physics.

Among the factors that appeared from the analysis of students' and teachers' interviews from both years were their complaints about the large class sizes. This issue was believed to prevent students from participating during physics lectures and teachers from being creative in their explanations. Also, some student participants from both years discussed how the provision of a suitable class environment affected their understanding of physics problems. Furthermore, in the interviews, the participants (students from both years and preparatory-year teachers) emphasised the importance of suitable facilities for helping students to learn and solve physics problems. Such facilities include, for example, providing suitable instructional tools that facilitate physics understanding, preparing classrooms or providing physics laboratories with suitable tools and equipment.

Moreover, the data analysis of interviews of teachers from both years emphasised the role of the university management and the Physics Department in influencing students' thinking and learning. Also, the findings highlighted the role of the University and the Physics Department administration and its influence on the teachers, which reflected on the students. Furthermore, the participating teachers from both years expressed the view that tests with multiple choice questions indirectly affected students' ways of dealing with problem-solving. According to them, such tests are problematic and do not support students' thinking in solving physics problems.

Also, the interview findings showed how the problems included in the mechanics syllabus played a role in understanding physics, and how the thinking and learning skills course taught in the preparatory-year played a role in helping the students in aspects of thinking when solving physics problems. The data suggest that students were satisfied with the summary booklets used in both years and the students gave reasons for not using a physics textbook, such as, for example, the difficulty of the language used in the book and its high price. The book is in English, so the teachers tend not to refer to the book. However, some students and teachers had critical views about the booklet they used instead. Also, the data addressed the issue of the thinking and learning skills syllabus in terms of its importance and its role in preparing students in problem-solving. Some participants (students and teachers from both years) claimed that thinking skills should be included within the physics syllabus, while another participant (preparatory-year teacher) believed the two should be kept separate.

8.3.5 Socio-cultural factors affecting students' learning of problem-solving in physics

This section addresses the fifth research question: "What are students' and teachers' perceptions of the socio-cultural factors impacting on students' learning of problem-solving in physics?"

The findings suggest that that societal structures, including, for instance, the family, push students to choose physics rather than their desired area of specialisation. Also, it appears that certain students study physics because of its positive reputation in the Saudi context regardless of their own interests, which might reflect on their comprehension of physics.

In addition, the data collected from students and teachers indicated that living conditions had a role in influencing students to learn physics. For example, the findings highlighted the role of economic conditions, the matter of teachers' employment and family conditions. These issues were found to impact on students' perspectives towards learning physics and made them disinterested in studying physics or thinking about solving physics problems.

Moreover, the qualitative data analysis revealed that society played a vital role in influencing students' learning of problem-solving in physics. Society was broadly described by the participants with a set of characteristics which either referred to the family environment, the university environment, school, or friends and colleagues. Moreover, some students explained how the society where students live made them unaccustomed to thinking, which played a vital role in influencing their understanding of physics problems.

Also, a number of participants among students and teachers from both years highlighted the influence of teachers' Arabic dialects on their understanding and thinking when dealing with mechanics problems. Students claimed they were unable to follow some teachers because of their foreign dialect or accent. On the other hand, students and teachers referred to the problem of English language in their understanding of physics problems, as they saw that English added to their difficulties in understanding physics, causing another burden on their understanding.

8.4 Contributions of this study

The current study has made significant contributions to knowledge and methodology in the field of problem-solving in physics education, as discussed below.

8.4.1 Contributions to knowledge

From a theoretical perspective, this study contributes to the field of problem-solving skills in physics education in the KSA context. Firstly, one of the noteworthy issues that appeared through the students' think aloud and interviews was that some students from both years seemed not to make a clear distinction between understanding a physics problem and devising a plan to solve it; they were confused between these two cognitive processes. They believed that devising a plan meant to search for the data and find the relevant physics laws while solving the physics problem. Also, no students from either year demonstrated that they implemented the step of looking back when given the physics problem during the think aloud protocol, except one student. If students have a deficiency in evaluation (looking back), this will lead to weaknesses in monitoring, and therefore reduce their ability to judge the appropriateness of a plan or to assess whether a solution is correct (Garrett, Mazzocco, & Baker, 2006). In this regard, cognitive processes need to be given greater emphasis in order to boost students' awareness of their own cognitive processes when dealing with physics problems, in order to guide and organize their thinking to achieve their desired learning goals.

Secondly, according to the findings, social and cultural aspects played an important role in affecting students' choice of specialisation. According to the interviews with first-year students (seven students) and teachers (four from both years), it was found that forcing students to study specific subjects (absence of choice) led to students' lack of readiness in the physics class. It contributed to their lack of attention to understanding physics problems and their indifference to their learning in the physics lectures.

Thirdly, some students had negative attitudes towards learning physics, as they had heard from their parents and colleagues that physics was very difficult and that it involved complex thinking, very hard work and difficult mathematical issues. As reported in Chapter Six, their minds seemed fixed on these negative terms, so they found themselves not ready to engage in learning physics at university. Therefore, during the transition from school to university, students held psychological beliefs and perceptions about their learning which might hinder their thinking process and negatively affect their problem-solving skills. Hence, students need to have suitable psychological tools to support their learning when they move to the university stage.

Fourthly, it was found that students from both years were influenced by the teacher's power and refrained from discussing with their teachers because of certain teachers' short temper or mistreatment of students who asked questions about physics. Thus, some students were afraid to ask their teachers due to the potential angry reaction of the teacher, or due to their fear of embarrassment in front of their classmates. Thus, results indicate that the teacher's power plays a role in preventing students from asking questions or thinking in physics lectures.

In this context, Scott and Mortimer (2006) stated that "authoritative discourse is closed to the points of view of others, with its direction having been set in advance by the teacher" (p.611). The issue of teacher's power has been discussed by various scholars (e.g. Buzzelli & Johnston, 2001; Cothran & Ennis, 1997; Uitto & Syrjala, 2008); the power of the teacher in the classroom can restrict the freedom of students and creates fear. Therefore, students need to have the freedom to think and ask their teachers if they do not understand physics problems, rather than being hesitant to use their thinking or ask their teachers, as demonstrated by students' interviews from both years in Chapter Six.

It is therefore recommended that teachers should shift from an authoritative mode to a dialogic mode, because the interaction between students themselves and their teachers, through dialogue, gives students the opportunity to develop their thinking. In this regard, Wegerif et al. (2010, p.614) reported that "in dialogues, voices interact in unpredictable ways to produce new perspectives that enable participants to see the topic of the dialogue in a new way". Thus, a safe learning environment should be created to develop students' ideas rather than preventing them interacting with the teacher. In this regard, it was reported in the literature that teachers need to develop students' ideas and comprehension in the classroom through involving students' voices and allowing them to engage in discussion and that this leads to generative thinking prior to getting the solution (Bungum, Bøe, & Henriksen, 2018; Mortimer & Scott, 2003; Wood, Galloway, Sinclair, & Hardy, 2018).

Therefore, teachers need to provide a safe classroom environment to encourage social interaction to enable students to think and access assistance from the teacher or from other students. Subsequently, this assistance would improve students' understanding of physics problems.

Fifthly, the physics classrooms context at the university is an important element because teaching, learning and social interaction need to take place while solving physics problems. Also, "knowledge is constructed in the social context of the classroom through language" (Chin, 2006, p.1316). According to Vygotsky's theory, it can be seen that if students do not receive encouragement from their teachers to learn solving physics problems, or teachers do not make room for students to participate with them, this impacts negatively on the interaction between students and teachers and between students themselves (interpsychological) within the physics classrooms context.

Sixthly, this study is a first endeavour to introduce new perspectives about problem-solving in physics in relation to the university context (preparatory-year and first-year) to gain a deeper understanding into why students have difficulty solving physics problems at the university level, through the lens of sociocultural theory. This study used an interpretive approach, in contrast with the previous quantitative studies on problem-solving in the KSA, which did not take into account the perceptions of university students and teachers. The current study has brought in sociocultural aspects that play a role in influencing students' learning of problem-solving in physics, including the influence of teachers' Arabic dialects and the importance of a friendly relationship between teacher and students. This perspective may contribute to revising the existing framework for the teaching and learning of physics in Saudi Arabia.

Seventhly, some first-year students believed that the teaching methods used by the teachers influenced student's understanding and they cause cognitive overload, because the teacher often moves to a new idea without any link or preparation. The data also emphasised on the importance of building a friendly relationship with the students during the physics lectures, because this gives students a wide horizon for thinking and interaction in physics lectures. On the other hand, giving students a chance to ask about what they do not understand may reduce the load of information on their mind. Moreover, the English language, in addition to the difficulties of understanding physics, caused a burden on students' understanding. Therefore, teachers should reduce the burden on students' cognitive capacity through building a friendly relationship with the students during the physics lectures and providing them with learning opportunities to discuss and ask questions and by guiding them during their learning when solving physics problems as a form of scaffolding.

8.4.2 Contribution to methodology

Most studies conducted in the KSA in the social sciences have adopted quantitative methodologies, particularly in the fields of education and problem-solving (e.g. Albaker, 2012; Aljebally, 2013; Alshaya, 2014, Sawafetah, 2008; Yaseen, 2013). In contrast, the current study followed an interpretive approach, which is justified by the fact that this research is not built upon an ontology of realism that views social reality as existing independently of the knower. Rather, in terms of its ontological assumptions, the study views the reality of the physics class as a reflection of a multitude of realities constructed by the actors

This reality is viewed as being socially constructed by students and teachers through their unique subjectivities and their own accounts of their perceptions of problem-solving in the teaching and learning of physics. Indeed, this study sought to investigate the perspectives of participants about the phenomenon of problem-solving at the university level within the Saudi social context.

In this study, a sequential mixed methods design was used to collect data through quantitative and qualitative instruments (classroom observations, interviews, think aloud protocols and quantitative tests). Although mixed methods research is not extensively used in social science research in the KSA, especially in physics education, it was helpful in this study to get a greater understanding of the research problem. Indeed, rather than only using either quantitative or qualitative tools, "mixed methods research is a good design to use if you seek to build on the strengths of both quantitative and qualitative data" (Creswell, 2012, p.535).

Therefore, it can be seen that using the interpretive approach contributes to the methodology in the field of science education in general and in physics education in particular in the KSA as this approach helped gain a better understanding of the university students' physics problem-solving.

8.5 Limitations of the study

This study has a number of limitations which need to be taken into consideration. First of all, in the current study the university teachers' and students' perspectives may not reflect the reality of all physics teachers and students in Saudi universities, because this study is not rooted in an objective conception of reality since its main concern was to investigate perceptions and it did not endeavour to generalise its findings. In addition, this study was conducted in Taif University which is located in the Western region of the KSA, so it is not possible to generalise the results to the KSA as a whole as there are significant social and cultural differences between each region of the country. Therefore, due to the constraints of this PhD research, it was not possible to have access to other universities.

Moreover, as education is segregated by gender in the KSA, this study was conducted with male university teachers and students only; therefore, female voices were absent. This can be viewed as another limitation of the current study.

Another limitation is that this study was conducted with preparatory-year and first-year students during the same academic year, rather than conducting this study over two years from the preparatory-year to the first-year, due to the limited resources and time.

Also, the current study included preparatory- and first-year students and teachers but did not include other stakeholders such as heads of physics departments, administrators, secondary teachers of physics or secondary school students, which is another limitation of this study. However, due to the limited time available from my sponsor, this would have been too difficult to implement.

Furthermore, another limitation is that other scientific specialities, such as biology, biotechnology and chemistry, were not investigated. Indeed, the current study only focused on teachers’ and students’ perceptions of students’ problem-solving in physics. This is because the physics speciality is my area of interest as I am a physics teacher in general secondary education and because of my experience in supervising physics pre-service teachers during initial teacher training. Finally, the main aim of this study was to investigate students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives, and this study did not look into students' developmental processes while solving physics problems.

8.6 Implications

The findings of the current study have a number of implications for university management, for physics teachers and for students, as presented below.

8.6.1 Implications for university management

The findings of this study demonstrate that the participating university teachers were not satisfied with the university policy of using a majority of multiple-choice tests in the final physics examinations, because these kinds of questions do not support students' thinking, lead them to memorise or answer randomly without any thinking, and do not allow teachers to evaluate students' skills in problem-solving. Based on this, teachers wanted the university administration to take their voices into account in regard to test design because, due to their practice and involvement, they are more aware of the practical problems encountered in the teaching of physics.

Another important issue mentioned in this study is the large class sizes, which reduced the chance for students to participate. This makes the students inactive learners in their zone of proximal development, which leads to overdependence on their teachers to receive the physics information. It leads to teachers relying on traditional practices such as assisting students to memorise physics information rather than encouraging them to ask or think. Therefore, class size is an issue that needs to be considered by the university management who should make an effort to reduce the number of students in the classes and also train teachers to deal with the excessive number of students.

With regard to the social and cultural aspects in this study, it was found that many students had been pressured by their families into choosing physics at university. As a result, these students were not interested in the subject and this, in turn, was reflected in their poor understanding. Thus, it is recommended that administrators in the university implement surveys for students before joining the university in order to investigate their wishes and help them identify an appropriate specialisation or provide counselling.

The findings also demonstrate that the teachers in this study were physics specialists but had not had any teacher training. This was either due to time constraints or because they had never been invited to such courses. This raises the importance of the preparation of university teachers and the provision of adequate professional training. Also, the administration of the university should reconsider the selection of university teachers based on pedagogical qualifications as this may improve students' performance in the physics classrooms and guide their thinking in the learning of physics.

Regarding the syllabus issues, it was found that students preferred to use the summarised booklets that their teachers made available rather than the expensive physics textbooks, which were difficult to understand, partly because they were written in English. Therefore, the administration in the university needs to develop their own physics books considering students' needs, encourage teachers to use them, and prevent students to rely on these summarised booklets. Regarding the content and the length, the physics books need to be shortened and more attractive in order to encourage students to rely on these books rather than on the summarised booklets.

The findings of the study indicate that the lack of suitable facilities, such as instructional tools, classroom equipment and technological tools, was a factor affecting their learning. Suitable facilities would make the physics classroom more enjoyable and promote their thinking and creativity while solving physics problems. In order to achieve this, it is important for the university to create appropriate conditions for students and teachers for proper learning to occur.

Also, in some cases, teachers were required to teach a course outside their area of expertise, but they believed this was detrimental to students' learning. It has been suggested in the literature (e.g. Poland, Colburn, & Long, 2017; Sanders, Borko & Lockard, 1993) that, if teachers teach an unfamiliar science area, they may act as novice teachers, in contrast to teaching areas in which they have a deep understanding. Thus, the university management and the Physics Department should avoid requiring them to teach courses out of their area of specialization. As a result, if teachers establish connections with their students in a subject they have mastered, they would be more likely to rouse their students' interest and meet their needs and, in turn, act as change agents in the physics classroom (Moore, 2008).

8.6.2 Implications for physics teachers

This study confirms that teachers' professional development is an essential element that needs to be considered in university programmes in order to "encourage and facilitate teachers to reflect on their learning and practices" (Mansour et al., 2014, p.970). This is because, as mentioned in Chapter Six, this is because all the teachers in both years (preparatory-year and first-year) in the current study had specialised in the physics and had not studied the pedagogical aspects related to teaching methods. This might be detrimental to students' learning because teachers' pedagogical content knowledge fundamentally impacts on students' learning (Keller et al., 2017). Thus, teachers need to prepare themselves in pedagogical content knowledge to guide their students' thinking and use the appropriate pedagogical aspects in light of the nature and demands of physics lectures. The teachers' lack of pedagogical content knowledge may explain the lack of diversity in teaching methods and teachers' reliance on traditional methods which depend on memorisation and rote learning.

The findings of this study demonstrate that the teacher's power towards students in the physics lectures can prevent students from asking questions or thinking in physics lectures. This creates an unsafe classroom environment which, in turn, limits the interaction between students and their teacher or between students themselves and impacts negatively on students' thinking and learning. In this regard, teachers should minimise their authoritarian attitude towards students as much as possible and establish a friendly relationship with their students in order to create a safe classroom environment, promote students' thinking, give them the freedom to ask and think and receive enough guidance from their teachers or peers while solving physics problems to enable them to develop within their ZPD.

Furthermore, the findings of this study showed that the interaction during physics lectures between the teacher and students or among students themselves was almost inexistent. Also, it was found that the reason behind the students' weak interaction was the absence of encouragement from teachers. Therefore, physics teachers need to pay more attention to building an interactive learning environment and to adopting appropriate pedagogical strategies in order to make the physics classroom more enjoyable and interesting.

Also, the findings of this study suggest that the physics teachers in schools either omit or summarise certain points of the physics syllabus which later negatively affect students' learning in physics when they move to university. This raises the importance of communication between schools and the university. For instance, university physics teachers could hold meetings with physics teachers in schools to discuss the issues they face in the teaching of physics because of the practice of omitting or summarising certain points in the syllabus. This may also be an opportunity to educate physics teachers in schools about the importance of all topics in the syllabus and their significance in students' learning at university as this syllabus provides basic physics knowledge to students before coming to university.

Furthermore, the current study can contribute to improving teaching and learning in the field of physics education by informing physics teachers about the perspectives of students and teachers in relation to learning and teaching physics and the factors that encourage or hinder students to use problem-solving skills in physics.

8.6.3 Implications for students

This study has emphasized that participating students had a lack of basic physics knowledge because they had become accustomed to memorising rather than thinking in school. Moreover, the results from the FCI questionnaire emphasized that students' scores on the basic concepts in mechanics were well below 60%. This strongly suggests that students' comprehension of Newtonian concepts was inadequate for successful problem-solving even though they had studied the dimensions included in the FCI questionnaire in secondary school. Therefore, this might draw their attention to the importance of gaining deep content knowledge in physics at the school and university levels.

8.7 Recommendations of the study

In the light of the limitations of this study, as reported above, this study might suggest future studies, as follows. Firstly, due to the constraints of this PhD research, it was not possible to have access to other universities in each region of the KSA to get a more comprehensive picture of students' problem solving in physics in higher education in Saudi Arabia through university teachers' and students' perspectives. Therefore, expanding this research to other universities could have helped reveal a set of sociocultural factors which may affect students' learning in physics across the wider Saudi context.

Secondly, as this study was only conducted with male participants, including female voices and investigating their views could give the study a deeper understanding of teachers’ and students’ perceptions of this issue and uncover other sociocultural factors affecting their learning in relation to gender.

Thirdly, due to the limited time, this study was conducted with preparatory-year and first-year students during the same academic year. However, conducting a longitudinal study with students over two years from the preparatory-year to the first-year would have helped gain a deeper understanding of their perceptions about students’ problem solving in physics. This may have been possible by following the students who move to the first-year and gain valuable information about their experiences about physics problems throughout their studies in the preparatory-year and the first-year.

Fourthly, including other stakeholders, such as heads of physics departments, administrators, secondary teachers of physics or secondary school students would have yielded further insights into stakeholders’ perceptions of students’ problems solving in physics in higher education in Saudi Arabia.

Fifthly, extending the current study to focus on other scientific disciplines could have provided more insights into teachers’ and students’ perceptions of problem-solving, which might have uncovered additional sociocultural factors affecting learning in science. However, due to time constraints, this was not possible.

Sixthly, further studies are needed to collect data over longer periods of time so that the measurement of the problem-solving ability might be conducted twice or several times in order to see how students develop their ability to solve physics problems over longer periods of time.

Finally, this study demonstrated how students were thinking during think aloud protocols when they dealt with a physics problem; therefore, it may be useful to conduct a study about how students think about their thinking and use metacognitive strategies when they deal with physics problems.

8.8 Final comments

This study can contribute to the development of physics education and curricula in the KSA through highlighting on teachers' and students' perceptions of students' problem-solving in physics in higher education in Saudi Arabia, and also through highlighting certain factors which affect students' learning in solving physics problems and prevent them from adequately solving physics problems at university.

Moreover, throughout my doctoral research journey, I have been able to extend my knowledge and experience. For example, conducting this study following an interpretive approach allowed me to engage with my participants and hear their voices about problem-solving in physics at the university. In addition, the current study attempted to take into consideration the sociocultural aspects as the sociocultural theory is based on the notion that context is an important contributor to the learning process and that interaction between people within this context influences learning. Thus, the main point is that the sociocultural theory is noteworthy in focussing on all aspects of the context that may influence physics problem-solving by shedding light on several aspects of the Saudi societal context. Therefore, adopting this theory allowed me to investigate the aspects which influence students' learning in solving physics problems in the Saudi context.

Furthermore, the use of a sequential mixed method design using quantitative and qualitative instruments allowed me to engage with a new research methodology in relation to problem-solving in physics since most studies conducted in the KSA and in other Gulf countries have followed quantitative methodologies, such as correlational or experimental studies or surveys and attitude studies.

Finally, I feel now that I have enhanced my academic and research skills throughout the period of conducting this study by looking at a variety of sources such as articles, books, websites and attending workshops at university; therefore, upon my return to Saudi Arabia, I will do my best to convey what I have learnt in this research through courses and seminars to develop teaching and learning physics and continue to carry out other research in this area.

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Appendix One: Certificate of Ethical Approval

GRADUATE SCHOOL OF EDUCATION

St Luke's Campus
Heavitree Road
Exeter UK EX1 2LU

http://socialsciences.exeter.ac.uk/education/

CERTIFICATE OF ETHICAL APPROVAL

Title of Project: An exploration of Saudi university teachers' and students' perceptions of problem solving skills in the teaching and learning of physics.

Researcher(s) name: Naif Ateeq Alsufyani

Supervisor(s): Nasser Mansour
Nigel Skinner

This project has been approved for the period

From: 21.02.2016
To: 21.05.2016

Ethics Committee approval reference:

D/15/16/19

Signature: Date: 01.01.2016
(Dr Philip Durrant, Chair, Graduate School of Education Ethics Committee)

Appendix Two: Participant's information sheet

INFORMATION SHEET AND CONSENT FORM FOR RESEARCH

Title of Research Project
An exploration of Saudi university teachers' and students' perceptions of problem solving skills in the teaching and learning of physics.

Details of Project
This project is to explore teachers' and students' perceptions of problem solving skills in the teaching and learning of physics and to identify the factors which might face teachers and students during solving physics problems in preparatory and 1st year physics in Taif university. I am currently a Ph.D student in Educational Research at the University of Exeter. All information I will collect from this study will be just treated for research purposes.
As a result, you are kindly requested to participate in this study. As a participant, I would be grateful if you could answer two questionnaires and take part in a face-face interview conducted by myself. In addition, your class may be observed for the purpose of the study

Contact Details
For further information about the research /interview *and* classroom observation data, please contact:

Name: *Naif Alsufyani*
Postal address: Graduate School of Education- Exeter University, St. Luke's Campus, Heavitree Road, Exeter, EX1 2LU, Critical Studies Unit.
Telephone: 00 44 (0)*7401908990*
Email: *naaa204@exeter.ac.uk*

If you have concerns/questions about the research you would like to discuss with someone else at the University, please contact: Dr. Nasser Mansour. N.Mansour@exeter.ac.uk

Confidentiality
Interview tapes, transcripts and classroom observation will be held in confidence. They will not be used other than for the purposes described above and third parties will not be allowed access to them (except as may be required by the law). However, if you request it, you will be supplied with a copy of your interview and classroom observation transcript so that you can comment on and edit it as you see fit (please give your email below so that I am able to contact you at a later date).Your data will be held in accordance with the Data Protection Act.

Data Protection Notice

Data collected will be stored in a secure and safe place. The digital recording of the interview and classroom observation will be stored locally on my personal computer is equipped with an up-to-date anti virus software and password-protected. The questionnaires will be kept in a locked cabinet that only the researcher has access to.
Interview transcripts and classroom observation will also be stored in my personal computer. Transcripts will not be printed. As a participant, you will be attributed a pseudonym, or equivalent, to ensure anonymity. All participants will be referred to as "participant 1, participant 2" and any written information collected will be destroyed by shredding and securely disposed when it is no longer needed upon completion of my research and after the submission of the thesis. Nobody but I, will have access to all the data and related files either in hard copy format or electronic format.

Page 1 of 2 Revised: December 2014

UNIVERSITY OF EXETER

INFORMATION SHEET AND CONSENT FORM FOR RESEARCH

You have also the right to withdraw from the research at any time. In addition anonymity and confidentiality will strictly be maintained. In the questionnaire no personal information that may identify you will be requested.

Anonymity

Interview data and classroom observation will be held and used on an anonymous basis, with no mention of your name, but we will refer to the group of which you are a member.

Consent

I have been fully informed about the aims and purposes of the project.
I understand that:

- there is no compulsion for me to participate in this research project and, if I do choose to participate, I may withdraw at any stage;
- I have the right to refuse permission for the publication of any information about me;
- any information which I give will be used solely for the purposes of this research project, which may include publications or academic conference or seminar presentations;
- If applicable, the information, which I give, may be shared between any of the other researcher(s) participating in this project in an anonymised form;
- all information I give will be treated as confidential;
- the researcher(s) will make every effort to preserve my anonymity.

.... (Signature of participant)	.... (Date)
.... (Printed name of participant)	.... (Email address of participant if they have requested to view a copy of the interview transcript and classroom observation.)
.... (Signature of researcher)	.... (Printed name of researcher)

One copy of this form will be kept by the participant; a second copy will be kept by the researcher(s). Your contact details are kept separately from your interview data.

Appendix Three: Consent form

UNIVERSITY OF EXETER

GRADUATE SCHOOL OF EDUCATION

Title of Research Project: An exploration of Saudi university teachers' and students' perceptions of problem solving skills in the teaching and learning of physics.

CONSENT FORM

I have been fully informed about the aims and purposes of the project.

I understand that:

there is no compulsion for me to participate in this research project and, if I do choose to participate, I may at any stage withdraw my participation and may also request that my data be destroyed

I have the right to refuse permission for the publication of any information about me

any information which I give will be used solely for the purposes of this research project, which may include publications or academic conference or seminar presentations

if applicable, the information, which I give, may be shared between any of the other researcher(s) participating in this project in an anonymised form

all information I give will be treated as confidential

the researcher(s) will make every effort to preserve my anonymity

............................………………..   ....
(Signature of participant)   (Date)

……………………
(Printed name of participant)

One copy of this form will be kept by the participant; a second copy will be kept by the researcher(s)

Contact phone number of researcher (Naif Alsufyani): UK 00447401908990- KSA 0503718116

If you have any concerns about the project that you would like to discuss, please contact:

- naaa204@exeter.ac.uk
OR
Knight1400@gmail.com

* when research takes place in a school, the right to withdraw from the research does NOT usually mean that pupils or students may withdraw from lessons in which the research takes place

Appendix Four: Permission from Taif University

بسم الله الرحمن الرحيم

Kingdom of Saudi Arabia
Ministry of Higher Education
Taif University
Vice President of Graduate Studies
and Scientific Research

المملكة العربية السعودية
وزارة التعليم العالي
جامعة الطائف
وكيل الجامعة للدراسات العليا
والبحث العلمي

جامعة الطائف
TAIF UNIVERSITY

سعادة الملحق الثقافي في بريطانيا **سلمه الله**

السلام عليكم ورحمة الله وبركاته **و بعد،**

إشارة إلى الطلب المقدم من مبتعث الجامعة/ نائف بن عتيق بن عبدالله السفياني (هوية وطنية/ ١٠٣٥٧٢٩٦٤٧) بخصوص حاجته للقيام برحلة علمية داخل جامعة الطائف، لتطبيق أدوات بحثه لمرحلة الدكتوراه، و ذلك بالقيام بمقابلات و توزيع استبيانات و تسجيل ملاحظات في القاعات الدراسية مع طلاب السنة التحضيرية في مسارها العلمي، و طلاب تخصص الفيزياء و أساتذتهم، و هو الأمر الذي أيده خطاب المشرف الأكاديمي عليه بجامعة (Exeter) ببريطانيا.

عليه نفيد سعادتكم بموافقتنا على قيام المبتعث بجمع البيانات المتعلقة برسالته لمرحلة الدكتوراه داخل جامعة الطائف اعتباراً من (٢٠١٦/٠٢/٢١م) و لمدة ثلاثة أشهر، و سيتم تحديد إسم المشرف على الرحلة العلمية من جامعة الطائف، بعد وصول الطلب الإلكتروني عبر بوابة المبتعثين (سفير) .

لإطلاع سعادتكم و التوجيه بما يلزم حياله.

و تقبلوا خالص التحية و التقدير ،،،

وكيل جامعة الطائف
للدراسات العليا و البحث العلمي

د. سعد بن سالم الزهراني

١٤٢٧/٤/١٥

الرقم: التاريخ: / / ١٤هـ المشفوعات:

الطائف - الحوية - ص. ب ٨٨٨ الرمز البريدي ٢١٩٧٤ - هاتف : ٧٢٧٢٠٢٠ (٠٢) تحويلة ٢١٦٦ - فاكس : ٧٢٧٢٠٩٥ (٠٢)
Taif - Al-Haweiah - P.O. Box 888 Zip Code 21974 - Tel.: (02) 727 2020 Ext. 2166 - Fax : (02) 727 2095

Appendix Five: FCI questionnaire

1. Two metal balls are the same size but one weighs twice as much as the other. The balls are dropped from the roof of a single story building at the same instant of time. The time it takes the balls to reach the ground below will be:
   (A) about half as long for the heavier ball as for the lighter one.
   (B) about half as long for the lighter ball as for the heavier one.
   (C) about the same for both balls.
   (D) considerably less for the heavier ball, but not necessarily half as long.
   (E) considerably less for the lighter ball, but not necessarily half as long.

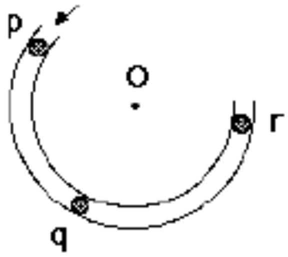
2. The two metal balls of the previous problem roll off a horizontal table with the same speed. In this situation:
   (A) both balls hit the floor at approximately the same horizontal distance from the base of the table.
   (B) the heavier ball hits the floor at about half the horizontal distance from the base of the table than does the lighter ball.
   (C) the lighter ball hits the floor at about half the horizontal distance from the base of the table than does the heavier ball.
   (D) the heavier ball hits the floor considerably closer to the base of the table than the lighter ball, but not necessarily at half the horizontal distance.
   (E) the lighter ball hits the floor considerably closer to the base of the table than the heavier ball, but not necessarily at half the horizontal distance.

3. A stone dropped from the roof of a single story building to the surface of the earth:
   (A) reaches a maximum speed quite soon after release and then falls at a constant speed thereafter.
   (B) speeds up as it falls because the gravitational attraction gets considerably stronger as the stone gets closer to the earth.
   (C) speeds up because of an almost constant force of gravity acting upon it.
   (D) falls because of the natural tendency of all objects to rest on the surface of the earth.
   (E) falls because of the combined effects of the force of gravity pushing it downward and the force of the air pushing it downward.

4. A large truck collides head-on with a small compact car. During the collision:
   (A) the truck exerts a greater amount of force on the car than the car exerts on the truck.
   (B) the car exerts a greater amount of force on the truck than the truck exerts on the car.
   (C) neither exerts a force on the other, the car gets smashed simply because it gets in the way of the truck.
   (D) the truck exerts a force on the car but the car does not exert a force on the truck.
   (E) the truck exerts the same amount of force on the car as the car exerts on the truck.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (5 and 6).

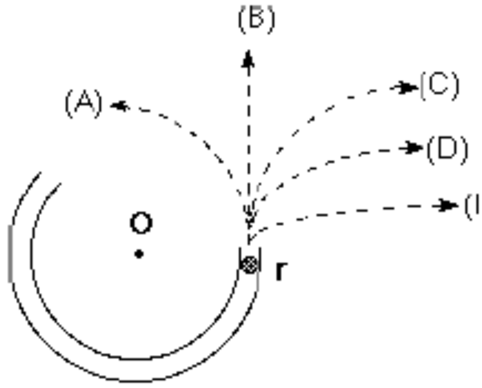
The accompanying figure shows a frictionless channel in the shape of a segment of a circle with center at "O". The channel has been anchored to a frictionless horizontal table top. You are looking down at the table. Forces exerted by the air are negligible. A ball is shot at high speed into the channel at "p" and exits at "r."



5. Consider the following distinct forces:
    1. A downward force of gravity.
    2. A force exerted by the channel pointing from q to O.
    3. A force in the direction of motion.
    4. A force pointing from O to q.

   Which of the above forces is (are) acting on the ball when it is within the frictionless channel at position "q"?

   (A) 1 only.
   (B) 1 and 2.
   (C) 1 and 3.
   (D) 1, 2, and 3.
   (E) 1, 3, and 4.

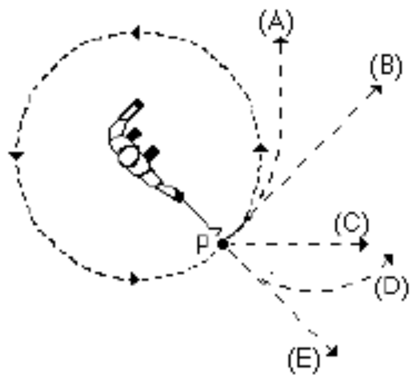


6. Which path in the figure at right would the ball most closely follow after it exits the channel at "r" and moves across the frictionless table top?

7. A steel ball is attached to a string and is swung in a circular path in a horizontal plane as illustrated in the accompanying figure.

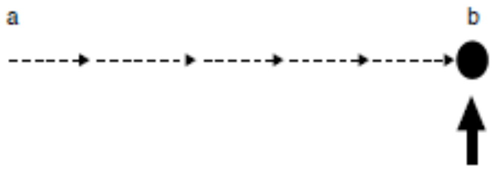
   At the point P indicated in the figure, the string suddenly breaks near the ball.

   If these events are observed from directly above as in the figure, which path would the ball most closely follow after the string breaks?

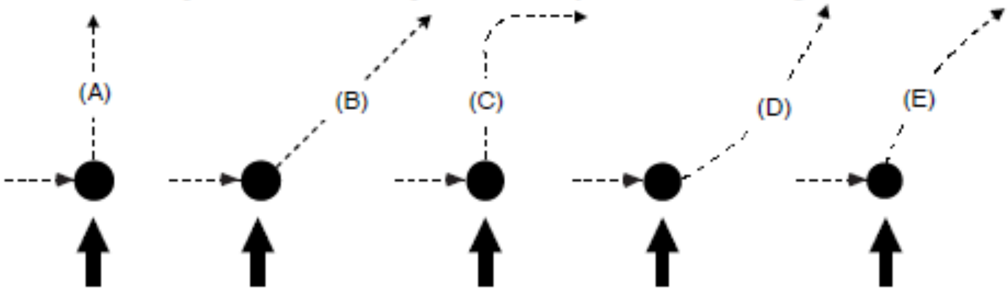


USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (8 through 11).

The figure depicts a hockey puck sliding with constant speed v_o in a straight line from point "a" to point "b" on a frictionless horizontal surface. Forces exerted by the air are negligible. You are looking down on the puck. When the puck reaches point "b," it receives a swift horizontal kick in the direction of the heavy print arrow. Had the puck been at rest at point "b," then the kick would have set the puck in horizontal motion with a speed v_k in the direction of the kick.



8. Which of the paths below would the puck most closely follow after receiving the kick ?

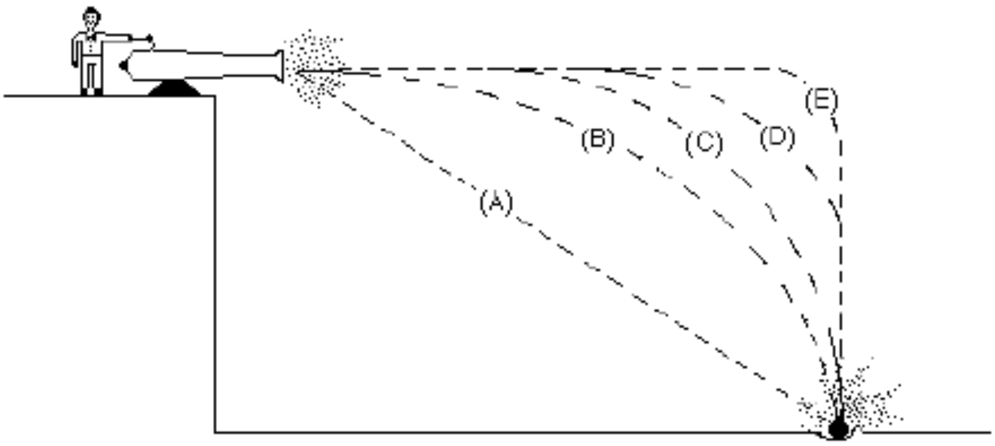


9. The speed of the puck just after it receives the kick is:
   (A) equal to the speed "v_o" it had before it received the kick.
   (B) equal to the speed "v_k" resulting from the kick and independent of the speed "v_o".
   (C) equal to the arithmetic sum of the speeds "v_o" and "v_k".
   (D) smaller than either of the speeds "v_o" or "v_k".
   (E) greater than either of the speeds "v_o" or "v_k", but less than the arithmetic sum of these two speeds.

10. Along the frictionless path you have chosen in question 8, the speed of the puck after receiving the kick:
   (A) is constant.
   (B) continuously increases.
   (C) continuously decreases.
   (D) increases for a while and decreases thereafter.
   (E) is constant for a while and decreases thereafter.

11. Along the frictionless path you have chosen in question 8, the main force(s) acting on the puck after receiving the kick is (are):
   (A) a downward force of gravity.
   (B) a downward force of gravity, and a horizontal force in the direction of motion.
   (C) a downward force of gravity, an upward force exerted by the surface, and a horizontal force in the direction of motion.
   (D) a downward force of gravity and an upward force exerted by the surface.
   (E) none. (No forces act on the puck.)

12. A ball is fired by a cannon from the top of a cliff as shown in the figure below. Which of the paths would the cannon ball most closely follow?



13. A boy throws a steel ball straight up. Consider the motion of the ball only after it has left the boy's hand but before it touches the ground, and assume that forces exerted by the air are negligible. For these conditions, the force(s) acting on the ball is (are):

(A) a downward force of gravity along with a steadily decreasing upward force.

(B) a steadily decreasing upward force from the moment it leaves the boy's hand until it reaches its highest point; on the way down there is a steadily increasing downward force of gravity as the object gets closer to the earth.

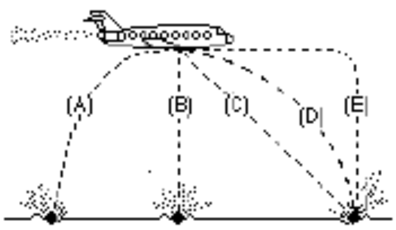
(C) an almost constant downward force of gravity along with an upward force that steadily decreases until the ball reaches its highest point; on the way down there is only a constant downward force of gravity.

(D) an almost constant downward force of gravity only.

(E) none of the above. The ball falls back to ground because of its natural tendency to rest on the surface of the earth.

14. A bowling ball accidentally falls out of the cargo bay of an airliner as it flies along in a horizontal direction.

As observed by a person standing on the ground and viewing the plane as in the figure at right, which path would the bowling ball most closely follow after leaving the airplane?



USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT TWO QUESTIONS (15 and 16).

A large truck breaks down out on the road and receives a push back into town by a small compact car as shown in the figure below.

15. While the car, still pushing the truck, is speeding up to get up to cruising speed:
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
    (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

16. After the car reaches the constant cruising speed at which its driver wishes to push the truck:
    (A) the amount of force with which the car pushes on the truck is equal to that with which the truck pushes back on the car.
    (B) the amount of force with which the car pushes on the truck is smaller than that with which the truck pushes back on the car.
    (C) the amount of force with which the car pushes on the truck is greater than that with which the truck pushes back on the car.
    (D) the car's engine is running so the car pushes against the truck, but the truck's engine is not running so the truck cannot push back against the car. The truck is pushed forward simply because it is in the way of the car.
    (E) neither the car nor the truck exert any force on the other. The truck is pushed forward simply because it is in the way of the car.

17. An elevator is being lifted up an elevator shaft at a constant speed by a steel cable as shown in the figure below. All frictional effects are negligible. In this situation, forces on the elevator are such that:

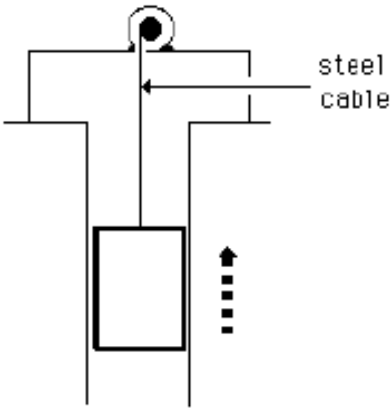
(A) the upward force by the cable is greater than the downward force of gravity.

(B) the upward force by the cable is equal to the downward force of gravity.

(C) the upward force by the cable is smaller than the downward force of gravity.

(D) the upward force by the cable is greater than the sum of the downward force of gravity and a downward force due to the air.

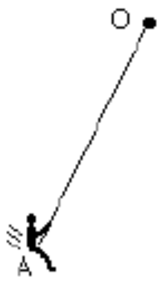
(E) none of the above. (The elevator goes up because the cable is being shortened, not because an upward force is exerted on the elevator by the cable).



Elevator going up
at constant speed

18. The figure below shows a boy swinging on a rope, starting at a point higher than A. Consider the following distinct forces:

1. A downward force of gravity.
2. A force exerted by the rope pointing from A to O.
3. A force in the direction of the boy's motion.
4. A force pointing from O to A.



Which of the above forces is (are) acting on the boy when he is at position A?

(A) 1 only.

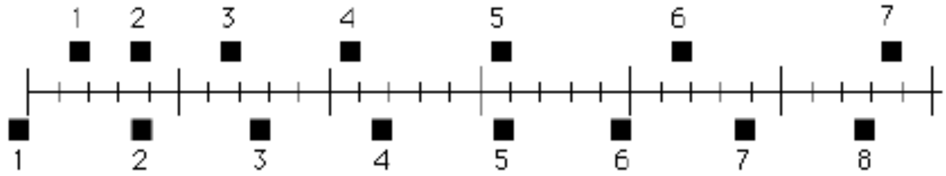
(B) 1 and 2.

(C) 1 and 3.

(D) 1, 2, and 3.

(E) 1, 3, and 4.

19. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



Do the blocks ever have the same speed?

(A) No.

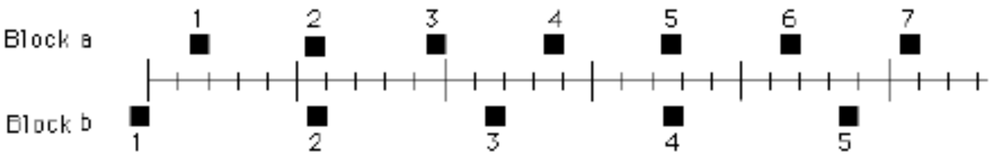
(B) Yes, at instant 2.

(C) Yes, at instant 5.

(D) Yes, at instants 2 and 5.

(E) Yes, at some time during the interval 3 to 4.

20. The positions of two blocks at successive 0.20-second time intervals are represented by the numbered squares in the figure below. The blocks are moving toward the right.



The accelerations of the blocks are related as follows:

(A) The acceleration of "a" is greater than the acceleration of " b".

(B) The acceleration of "a" equals the acceleration of "b". Both accelerations are greater than zero.

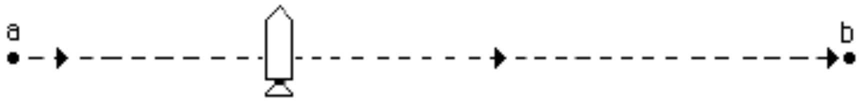
(C) The acceleration of "b" is greater than the acceleration of "a".

(D) The acceleration of "a" equals the acceleration of "b". Both accelerations are zero.

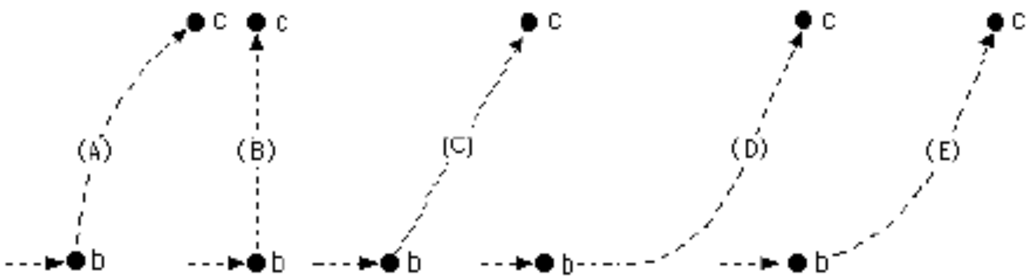
(E) Not enough information is given to answer the question.

USE THE STATEMENT AND FIGURE BELOW TO ANSWER THE NEXT FOUR QUESTIONS (21 through 24).

A rocket drifts sideways in outer space from point "a" to point "b" as shown below. The rocket is subject to no outside forces. Starting at position "b", the rocket's engine is turned on and produces a constant thrust (force on the rocket) at right angles to the line "ab". The constant thrust is maintained until the rocket reaches a point "c" in space.

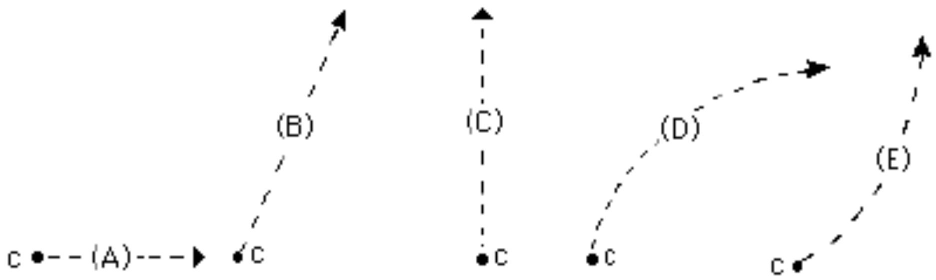


21. Which of the paths below best represents the path of the rocket between points "b" and "c"?



22. As the rocket moves from position"b" to position "c" its speed is:
    (A) constant.
    (B) continuously increasing.
    (C) continuously decreasing.
    (D) increasing for a while and constant thereafter.
    (E) constant for a while and decreasing thereafter.

23. At point "c" the rocket's engine is turned off and the thrust immediately drops to zero. Which of the paths below will the rocket follow beyond point "c"?



24. Beyond position "c" the speed of the rocket is:
    (A) constant.
    (B) continuously increasing.
    (C) continuously decreasing.
    (D) increasing for a while and constant thereafter.
    (E) constant for a while and decreasing thereafter.

25. A woman exerts a constant horizontal force on a large box. As a result, the box moves across a horizontal floor at a constant speed "v_o".

The constant horizontal force applied by the woman:

(A) has the same magnitude as the weight of the box.

(B) is greater than the weight of the box.

(C) has the same magnitude as the total force which resists the motion of the box.

(D) is greater than the total force which resists the motion of the box.

(E) is greater than either the weight of the box or the total force which resists its motion.

26. If the woman in the previous question doubles the constant horizontal force that she exerts on the box to push it on the same horizontal floor, the box then moves:

(A) with a constant speed that is double the speed "v_o" in the previous question.

(B) with a constant speed that is greater than the speed "v_o" in the previous question, but not necessarily twice as great.

(C) for a while with a speed that is constant and greater than the speed "v_o" in the previous question, then with a speed that increases thereafter.

(D) for a while with an increasing speed, then with a constant speed thereafter.

(E) with a continuously increasing speed.

27. If the woman in question 25 suddenly stops applying a horizontal force to the box, then the box will:

(A) immediately come to a stop.

(B) continue moving at a constant speed for a while and then slow to a stop.

(C) immediately start slowing to a stop.

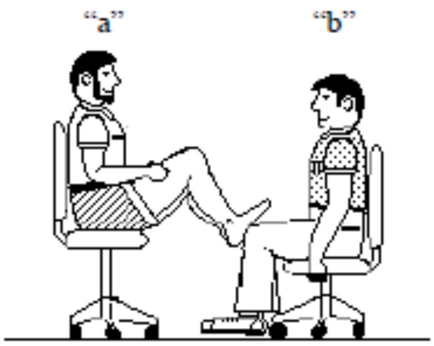
(D) continue at a constant speed.

(E) increase its speed for a while and then start slowing to a stop.

28. In the figure at right, student "a" has a mass of 95 kg and student "b" has a mass of 77 kg. They sit in identical office chairs facing each other.

Student "a" places his bare feet on the knees of student "b", as shown. Student "a" then suddenly pushes outward with his feet, causing both chairs to move.

During the push and while the students are still touching one another:



(A) neither student exerts a force on the other.

(B) student "a" exerts a force on student "b", but "b" does not exert any force on "a".

(C) each student exerts a force on the other, but "b" exerts the larger force.

(D) each student exerts a force on the other, but "a" exerts the larger force.

(E) each student exerts the same amount of force on the other.

29. An empty office chair is at rest on a floor. Consider the following forces:

1. A downward force of gravity.
2. An upward force exerted by the floor.
3. A net downward force exerted by the air.

Which of the forces is (are) acting on the office chair?

(A) 1 only.

(B) 1 and 2.

(C) 2 and 3.

(D) 1, 2, and 3.

(E) none of the forces. (Since the chair is at rest there are no forces acting upon it.)

30. Despite a very strong wind, a tennis player manages to hit a tennis ball with her racquet so that the ball passes over the net and lands in her opponent's court.
Consider the following forces:

1. A downward force of gravity.
2. A force by the "hit".
3. A force exerted by the air.

Which of the above forces is (are) acting on the tennis ball after it has left contact with the racquet and before it touches the ground?

(A) 1 only.

(B) 1 and 2.

(C) 1 and 3.

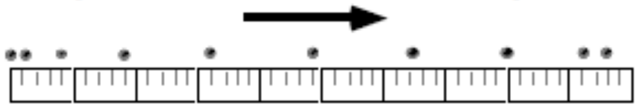
(D) 2 and 3.

(E) 1, 2, and 3.

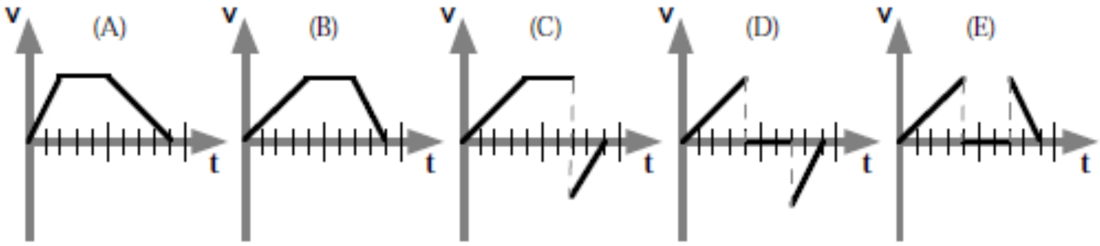
Appendix Six: MBT questionnaire

Mechanics Baseline Test

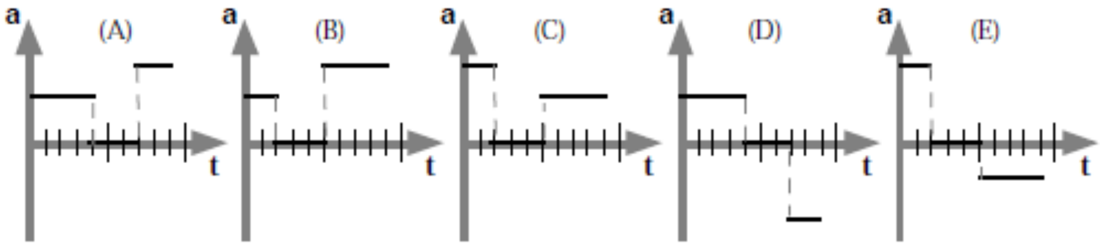
Refer to the diagram below when answering the first two questions. This diagram represents a multiflash photograph of an object moving along a horizontal surface. The positions as indicated in the diagram are separated by equal time intervals. The first flash occurred just as the object started to move and the last flash just as it came to rest.



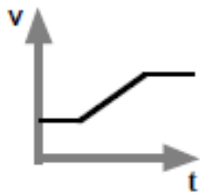
1. Which of the following graphs best represents the object's velocity as a function of time?

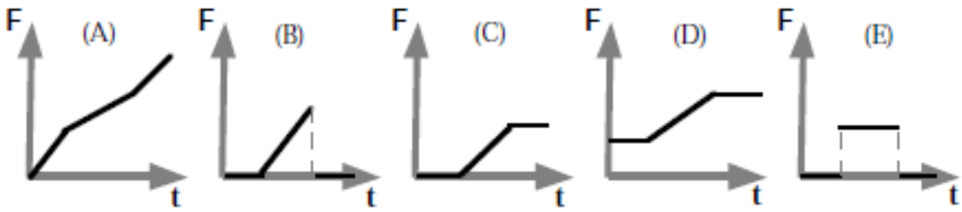


2. Which of the following graphs best represents the object's acceleration as a function of time?



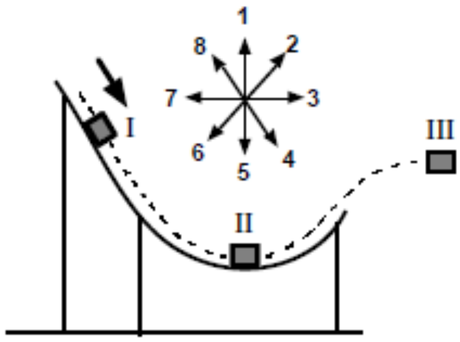
3. The velocity of an object as a function of time is shown in the graph at the right. Which graph below best represents the net force *vs* time relationship for this object?





Refer to the diagram on the right when answering the next three questions.

The diagram depicts a block sliding along a frictionless ramp. The eight numbered arrows in the diagram represent directions to be referred to when answering the questions.

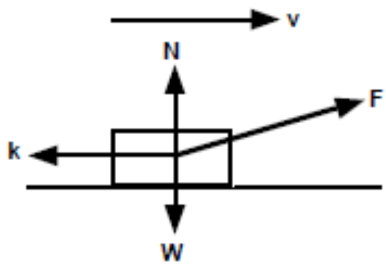


4. The direction of the acceleration of the block, when in position I, is best represented by which of the arrows in the diagram?
(A) 1 (B) 2 (C) 4 (D) 5
(E) None of the arrows; the acceleration is zero.

5. The direction of the acceleration of the block, when in position II, is best represented by which of the arrows in the diagram?
(A) 1 (B) 3 (C) 5 (D) 7
(E) None of the arrows; the acceleration is zero.

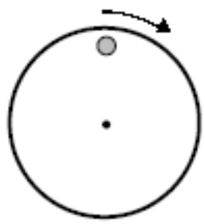
6. The direction of the acceleration of the block (after leaving the ramp) at position III, is best represented by which of the arrows in the diagram?
(A) 2 (B) 3 (C) 5 (D) 6
(E) None of the arrows; the acceleration is zero.

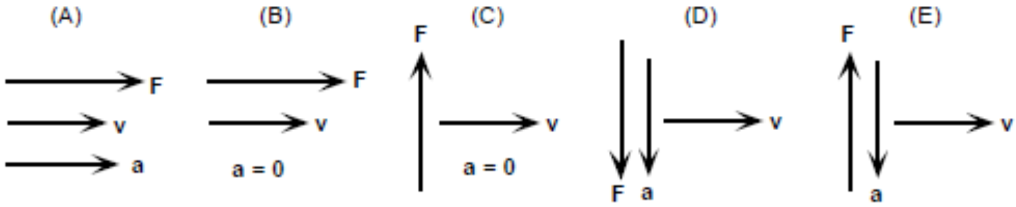
7. A person pulls a block across a rough horizontal surface at a **constant speed** by applying a force **F**. The arrows in the diagram correctly indicate the directions, but not necessarily the magnitudes of the various forces on the block. Which of the following relations among the force magnitudes W, k, N and F **must be true**?



(A) F = k and N = W
(B) F = k and N > W
(C) F > k and N < W
(D) F > k and N = W
(E) None of the above choices

8. A small metal cylinder rests on a circular turntable, rotating at a constant speed as illustrated in the diagram at the right. Which of the following sets of vectors best describes the velocity, acceleration, and net force acting on the cylinder at the point indicated in the diagram?

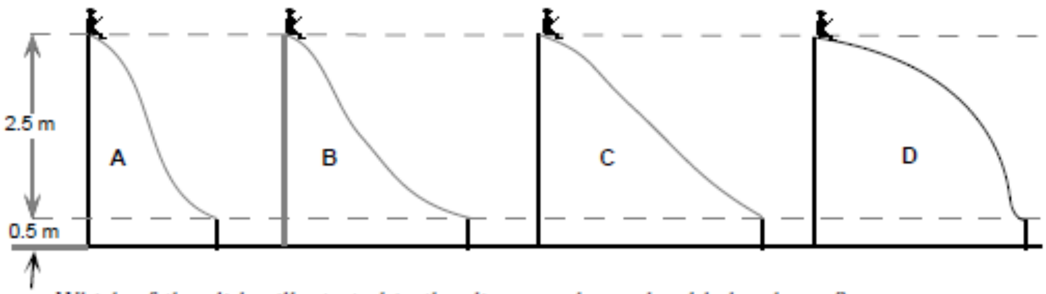




9. Suppose that the metal cylinder in the last problem has a mass of 0.10 kg and that the coefficient of static friction between the surface and the cylinder is 0.12. If the cylinder is 0.20 m from the center of the turntable, what is the maximum speed that the cylinder can move along its circular path without slipping off the turntable?

(A) $0 < V \leq 0.5$ m/s
(B) $0.5 < v \leq 1.0$ m/s
(C) $1.0 < v \leq 1.5$ m/s
(D) $1.5 < v \leq 2.0$ m/s
(E) $2.0 < v \leq 2.5$ m/s

10. A young girl wishes to select one of the **frictionless** playground slides illustrated below to give her the greatest possible speed when she reaches the bottom of the slide.

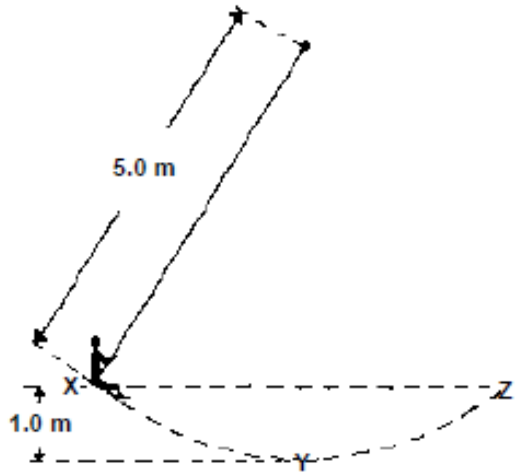


Which of the slides illustrated in the diagram above should she choose?

(A) A (B) B (C) C (D) D
(E) It doesn't matter; her speed would be the same for each.

Refer to the diagram below when answering the next two questions.

X and Z mark the highest and Y the lowest positions of a 50.0 kg boy swinging as illustrated in the diagram to the right.



11. What is the boy's speed at point Y?

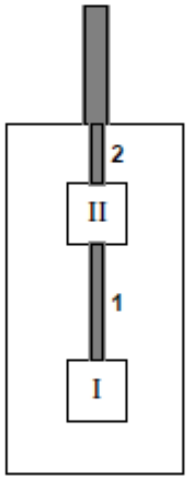
(A) 2.5 m/s (B) 7.5 m/s
(C) 10. m/s (D) 12.5 m/s
(E) None of the above.

12. What is the tension in the rope at point Y?

(A) 250 N (B) 525 N
(C) 7×10^2 N (D) 1.1×10^3 N
(E) None of the above.

Refer to the diagram below when answering the next two questions.

Blocks I and II, each with a mass of 1.0 kg, are hung from the ceiling of an elevator by ropes 1 and 2.



13. What is the force exerted by rope 1 on block I when the elevator is traveling upward at a constant speed of 2.0 m/s?

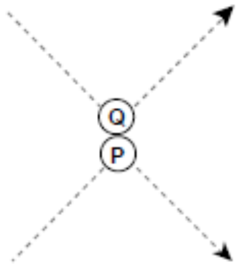
(A) 2 N (B) 10 N (C) 12 N
(D) 20 N (E) 22 N

14. What is the force exerted by rope 1 on block II when the elevator is stationary?

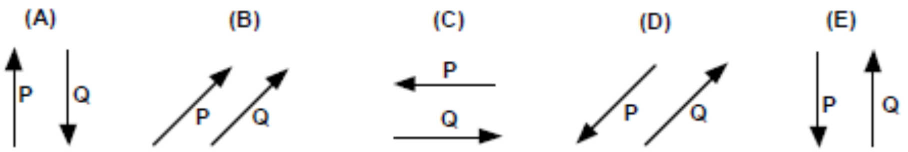
(A) 2 N (B) 10 N (C) 12 N
(D) 20 N (E) 22 N

Refer to the following diagram when answering the next two questions.

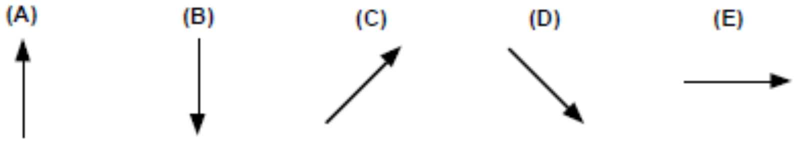
The diagram to the right depicts the paths of two colliding steel balls, P and Q.



15. Which set of arrows best represents the direction of the change in momentum of each ball?



16. Which arrow best represents the direction of the impulse applied to ball Q by ball P during the collision?



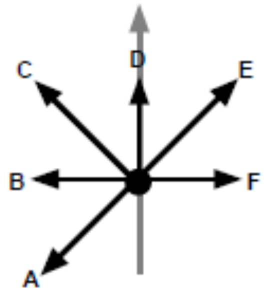
17. A car has a maximum acceleration of 3.0 m/s^2. What would its maximum acceleration be while towing a second car twice its mass?

(A) 2.5 m/s^2 (B) 2.0 m/s^2 (C) 1.5 m/s^2 (D) 1.0 m/s^2 (E) 0.5 m/s^2

18. A woman weighing 6.0×10^2 N is riding an elevator from the 1st to the 6th floor. As the elevator approaches the 6th floor, it decreases its upward speed from 8.0 m/s to 2.0 m/s in 3.0 s. What is the average force exerted by the elevator floor on the woman during this 3.0 s interval?

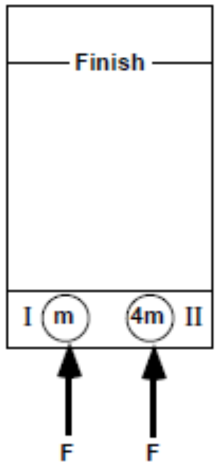
(A) 120 N (B) 480 N (C) 600 N (D) 720 N (E) 1200 N

19. The diagram at right depicts a hockey puck moving across a **horizontal, frictionless** surface in the direction of the dashed arrow. A constant force **F**, shown in the diagram, is acting on the puck. For the puck to experience a net force **in the direction of the dashed arrow**, another force must be acting in which of the directions labeled **A, B, C, D, E**?



(A) **A** (B) **B** (C) **C** (D) **D** (E) **E**

Refer to the diagram below when answering the next three questions.



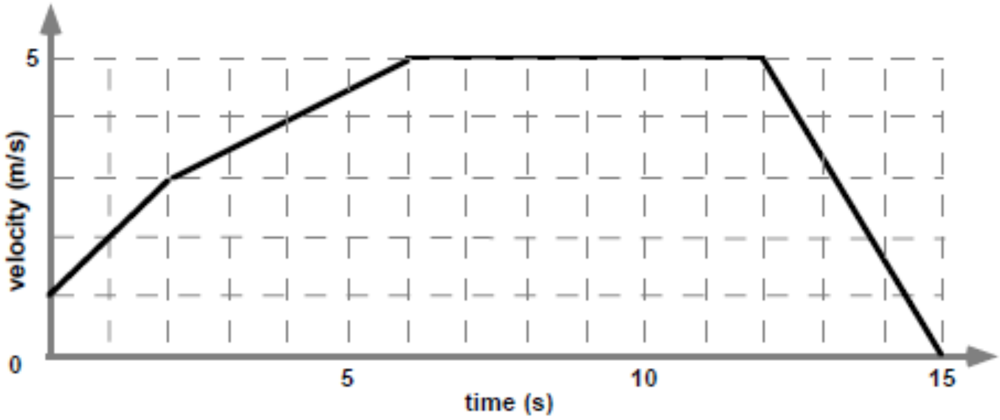
The diagram depicts two pucks on a frictionless table. Puck II is four times as massive as puck I. Starting from rest, the pucks are pushed across the table by two **equal** forces.

20. Which puck will have the greater kinetic energy upon reaching the finish line?
    (A) I (B) II
    (C) They both have the same amount.
    (D) Too little information to answer.

21. Which puck will reach the finish line first?
    (A) I (B) II
    (C) They will both reach the finish line at the same time.
    (D) Too little information to answer.

22. Which puck will have the greater momentum upon reaching the finish line?
    (A) I (B) II
    (C) They will both have the same momentum.
    (D) Too little information to answer.

Refer to the following graph of velocity *vs* time when answering the next three questions.



The graph represents the motion of an object moving in one dimension.

23. What was the object's average acceleration between t = 0 s and t = 6.0 s?
(A) 3.0 m/s^2 (B) 1.5 m/s^2 (C) 0.83 m/s^2 (D) 0.67 m/s^2
(E) None of the above.

24. How far did the object travel between t = 0 s and t = 6.0 s?
(A) 20. m (B) 8.0 m (C) 6.0 m (D) 1.5 m
(E) None of the above.

25. What was the average speed of the object for the first 6.0 s?
(A) 3.3 m/s (B) 3.0 m/s (C) 1.8 m/s (D) 1.3 m/s
(E) None of the above.

Refer to the diagram in the right margin to answer the following question.

The figure represents a multiflash photograph of a small ball being shot straight up by a spring. The spring, with the ball atop, was initially compressed to the point marked X and released. The ball left the spring at the point marked Y, and reaches its highest point at the point marked Z.

26. Assuming that air resistance is negligible;
    - (A) The acceleration of the ball was greatest just before it reached point Y (still in contact with the spring).
    - (B) The acceleration of the ball was decreasing on its way from point Y to point Z.
    - (C) The acceleration of the ball was zero at point Z.
    - (D) All of the above responses are correct.
    - (E) The acceleration of the ball was the same for all points in its trajectory from points Y to Z.

Appendix Seven: Interview schedule (students)

1. What are the steps of *problem-solving*?
2. How do you deal with these when you are solving physics problems?
3. When attempting to solve a problem, how do you proceed in general?
4. To what extent do you think that using problem-solving skills will help you to understand physics?
5. According to you, what makes solving physics problems more difficult/easier?
6. What do you think of the KSA recent educational reforms (the Developing Science and Mathematics Curriculum Project) and the new subjects that learned last year?
7. What do you think of the thinking skills subject you studied this year/last year?
8. What do you find most difficult in physics? Why?
9. How do you solve problems in class?
10. What do you think of your textbooks and the problems presented?
11. How does the university environment affect the way you think in comparison to school, and why?
12. What are the main differences between school and university in terms of physics problem-solving?
    a. Why?
    b. What did you find easier/harder…?
13. What topics did you find hard to understand so far?
    a. What could have helped you to better grasp these topics?
14. What topics did you find easy to understand so far? Why?

15. In physics, what are the most important elements that a student should be aware of and bear in mind in order to deal with mechanical problems?
16. In your opinion, what is absolutely necessary for any student to be able to solve physics problem?
17. How do you use your prior knowledge?
18. With your peers, how do you tackle difficult physics problem?
19. What do you like/dislike about physics lessons? Why?
20. In your opinion, how does physics relate to your daily lives?
21. How do you think students could be taught problem-solving skills? Why?
22. How is physics taught at schools and the university?
23. When you attend physics lessons, how do you interact with your teachers or your peers when solving problems? Why?
24. How do you deal with unfamiliar problems?
25. In opinion, what is the role of mathematics in physics?
26. What is the importance of the English language in terms of problem-solving in physics? Why?
27. Would do you like to add at the end of this interview?
28. Would you like to take part in a think aloud protocol?

Appendix Eight: Interview schedule (teachers)

1. What are the steps of *problem-solving*?
2. What are the main difficulties you face in teaching physics problems with your students? Why?
3. Do you believe that problem-solving skills can make students participate in physics lessons? Explain?
4. How do you think that students' problem-solving skills can be enhanced?
5. How often do you use problem-solving skills in physics lectures?
6. How do students interact with you and with their peers when solving problems? Why?
7. To what extent do you think you are prepared to deal with teaching thinking skills such as problem-solving skills in your physics lessons?
8. How do you know when students use problem-solving skills in class?
9. What do you think of the thinking skills subject in the preparatory-year?
10. What do you think of the physics textbooks and the problems which are presented in these textbooks?
11. In your opinion, what is the best way to teach students problem-solving in physics? And why?
12. What teaching methods do you usually use in teaching physics?
13. How could teaching methods make a difference in terms of students' interest in learning physics?
14. Do you think that the students should be taught problem-solving skills? Why?
15. In your opinion, what are the main elements that influence the way you teach physics?
16. Have you attended any training or workshop in relation to students' learning or thinking skills such as problem-solving skills? Why? Why not?
17. What is the importance of the English language in terms of problem-solving in physics? Why? Do you have any examples?
18. Do you like to add further comments at the end of this interview?

Appendix Nine: Observation schedule

Teacher code:		
Date		
Class		
Level (Prep-Year/first-year)		
Topic		
Item		**Comments**
Steps of problem-solving	Understanding the problem	
	Devising a plan	
	Carrying out the plane	
	Evaluating the solution	
What does a teacher focus on in relation to the steps of problem-solving skills?		
Nature of activity/ content		
Materials/ teaching aids		
The nature of questions		
Explaining activity and how it relates to previous lessons		
Discussing students' prior knowledge		
Teaching methods		
Helping students reasoning through thinking process or / feeding information		
Looking for correct answer or following the steps of problems		
Teacher's language		
Interaction	**Teacher-students**	
	Students-students	
Other comments		

Appendix Ten: Think aloud protocol

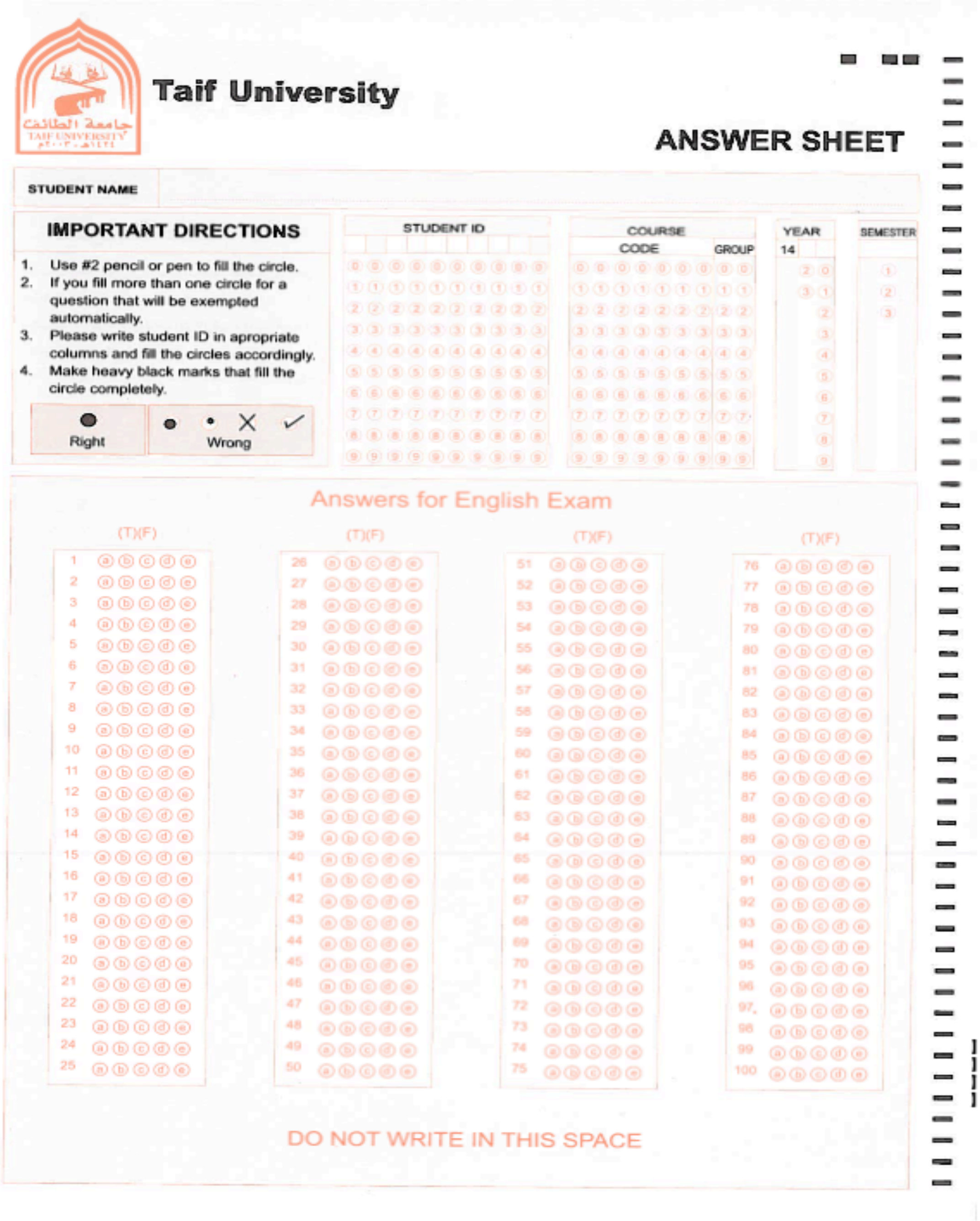
Dear student,

The following task consists of a physics problem that you need to solve. I am interested to understand better how students solve this problem. I would like you to read this task and think out loudly while you are solving the physics problem. Please, try to speak about what you are thinking about the problem and do not be under pressure. What are you doing here will not affect your results in physics at all. I cannot help you to solve this problem, but I will be here to record your thinking aloud.

Look at the following problem and use the provided pencil and paper. How would you solve it? Could you think aloud, please?

A box weighs 562 Newton on a tilted surface at a 30-degree angle. The force of gravity has two components, one perpendicular and one parallel to the incline. Find the two components of the weight force.

Appendix Eleven: Answer sheet



Taif University

ANSWER SHEET

STUDENT NAME

IMPORTANT DIRECTIONS

1. Use #2 pencil or pen to fill the circle.
2. If you fill more than one circle for a question that will be exempted automatically.
3. Please write student ID in apropriate columns and fill the circles accordingly.
4. Make heavy black marks that fill the circle completely.

Right

Wrong

STUDENT ID

COURSE

CODE

GROUP

YEAR

14

SEMESTER

Answers for English Exam

(T)(F)

DO NOT WRITE IN THIS SPACE

Appendix Twelve: An example of the process of qualitative data analysis

An example of the process of data analysis from a selection of raw data from interviews, classroom observations and think aloud protocols

Raw data	Code	Category	Theme
"Students in physics class don't care about the lecture, they are browsing their mobile phones. This is due to students do not find anything encourage them to interact with their teachers; therefore, they won't think about anything else" (S13P).	Lack of interaction	interaction	Perspectives on physics teaching methods
"If there was enthusiasm from the teacher, this would have helped us to interact with the teacher, but the fact is, that here in university, there is nothing makes us want to interact and understand in solving physics problems" (S10F)	Increasing student interaction		
it was noted that only four students participated in the discussion with the teacher out of a total of 37 students. The rest were not following the teacher and were occupied with their mobile phones or sleeping while others chatted with their classmates about topics irrelevant to physics (O1F)	Interaction in the classroom		
"There is no diversity in the teaching method in physics lectures. Meaning that if there is excitement or co-operative learning or the teacher makes the class active in a way that attract the students to the scientific material, the student will, as a result, understand the method of solving" (S3F).		Physics teaching methods in the university	
"lecturing was the main focus, meaning that it was a memorization process. Focus on the memorization process in the years before university negatively reflects on our students in university. Meaning that, teaching methods, unfortunately, in schools, do not accustom students to reaching their own conclusions, thinking and solving problem, these skills do not exist in the student's mind, and are almost non-existent. These are essential for subjects like solving physics problems" (T5P).		Physics teaching methods in schools	
"a lack of basic physics knowledge from school influences the level of students' thinking when they want to understand solving problems in physics" (T6F)		lack of basic physics knowledge	Students' lack of basic knowledge at different levels of the education system
"To be honest, my knowledge about physics concepts in general is superficial, and the teacher thinks that we have a fair basis about the mechanics physics concepts, so while the teacher progresses rapidly through the explanation, I keep thinking about the meaning of this concept during solving physics problems" (S3F).		lack of basic physics conceptual understanding	
"there were a number of physics concepts related to force types which the teacher did not clarify, for instance the concepts of conservative and non-conservative force" (O3F). Also, "when the			

teacher solved the following mechanics problem: "In the Cartesian coordinate system, find the equation of both instantaneous velocity and instantaneous acceleration", it had not been discussed with the students whether the concepts in the mechanics problem were clear or not" (O5F).			
"our preparation in school was shallow without depth in mathematics and this reflected on our understanding of physics problems" (S3F)		Lack of basic mathematical knowledge	
"The numerous accents and languages of the teachers, like the Moroccan and the Algerian, sometimes cause me problems. To be honest with you, the Tunisian, the Moroccan and the Algerian sometimes say vocabulary that is considered weird to some extent. I don't understand them and that's what sometimes causes me difficulty in following the teacher when dealing with the mechanics problems and, therefore, I cannot participate with him" (S3F)	accents of the teachers	Language issues	socio-cultural factors affecting students to learn problems solving in physics
"my desire was to study biology but one of my brother's specialism was biology, so my family insisted that I enrol in the specialism of physics. So, I study physics with no desire; that's the reason why I do not care to understand it well" (S5F)		Society forcing the student to choose a speciality	
"students choose scientific specialisations rather than humanities and the social sciences at the expense of their desires because in our culture, scientific specialisations are better than others for employment"(S15P).			
"in the physics classroom, there are about 60 students, because it's a preparatory-year and the numbers are huge, so sometimes the teacher's voice doesn't reach us clearly and therefore, it is difficult to understand physics problems" (S12P)		Classroom environment	institutional factors affecting students to learn problems solving in physics
"the thing that bothers me is the large number of almost 46 physics students in my class. I was previously teaching around 25 students, so I could innovate with them in teaching methods and in thinking when solving physics problems" (T4F)			
"I'm…. mmm I'm trying to imagine the problem in order to define the coordinates. First of all, ahh, okay, this coordinate is X with sine of the angle 30, and another one is Y with cosine of the angle 30. *mmm…* then, this is the tilted surface, *mmm*…what I have to do now is to find the required point which is… *mmm…* Find the two components of the weight force, but..ahh, I do not understand this […]. I feel that the solution requires something based on something else and this is a difficulty that confuses my understanding." (TAPS3).		Understanding the problem	Problem-solving strategies used by students
"What is this? This is the first time to see like this problem, mmm…I do not understand the mechanics problem" (TAPS16)			